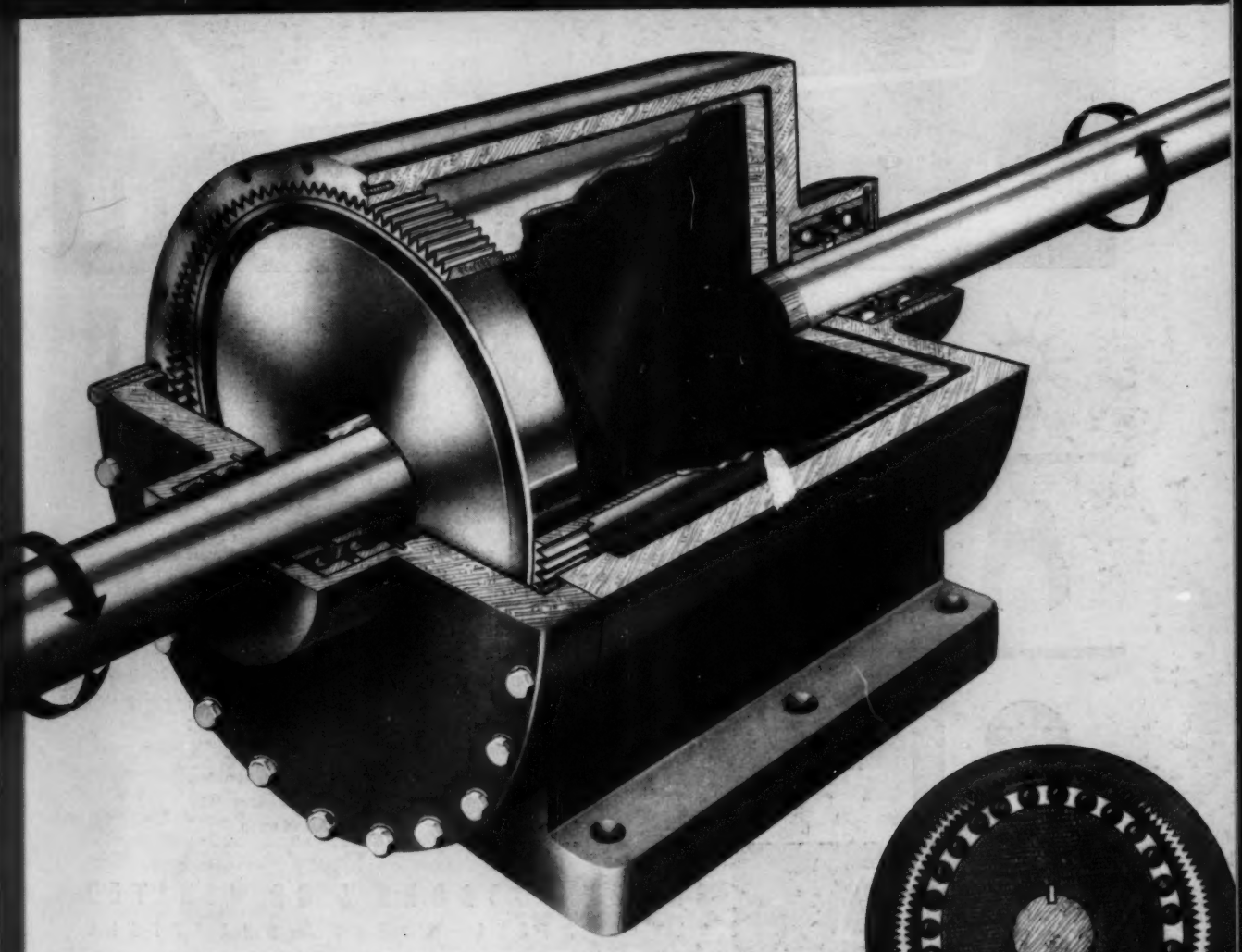
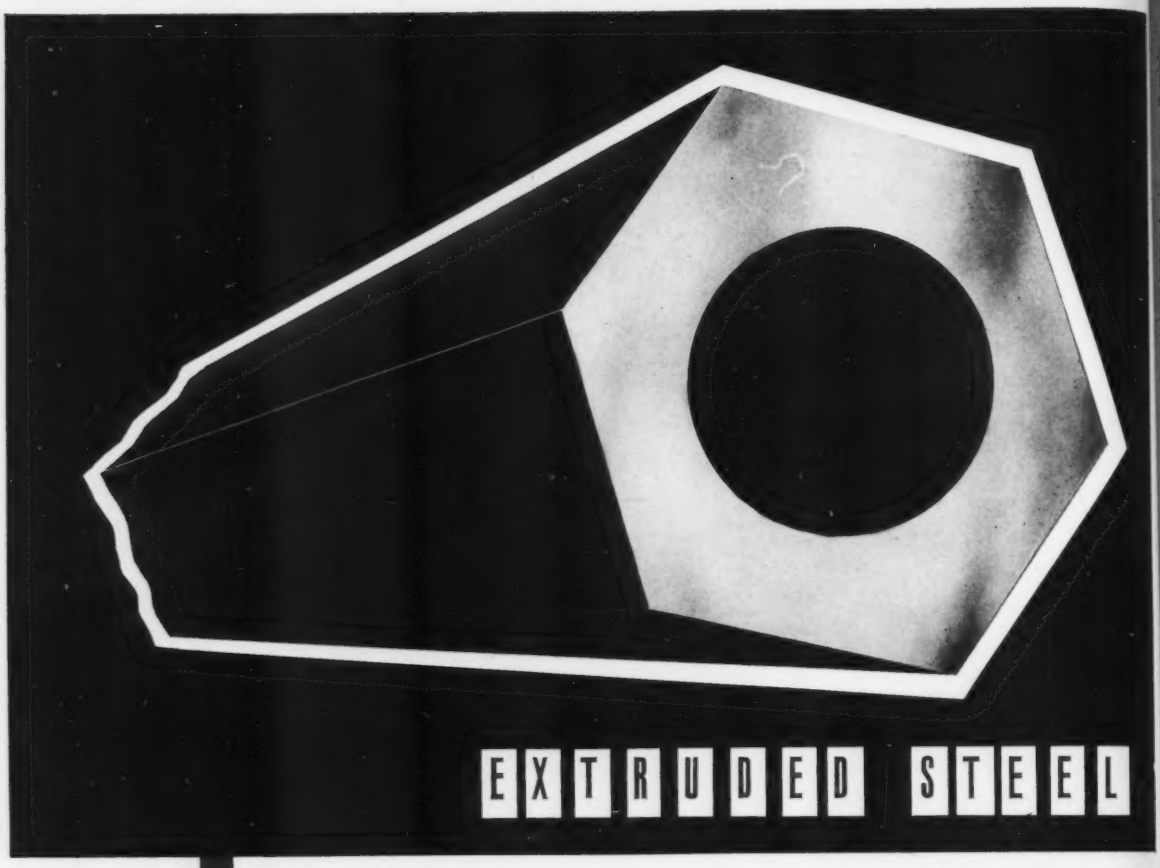
# ngineering Materials and Design



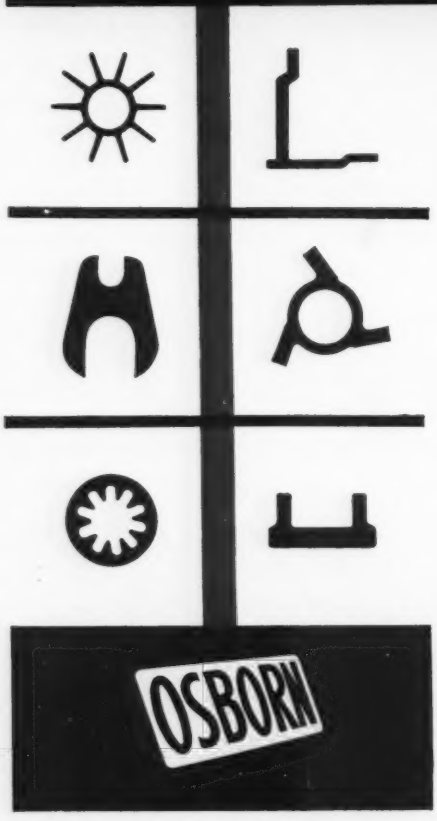
**Harmonic drive uses flexible toothed element** *page 84*

EMD 5543 for further information



EXTRUDED STEEL

# SECTIONS



Extruded steel sections are produced in most qualities of steel, including carbon and alloy steels, stainless steels and special alloys.

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# Engineering Materials and Design

★ *The Magazine for Engineering Designers*

A HEYWOOD PUBLICATION

**Vol. 4 No. 2 February 1961**



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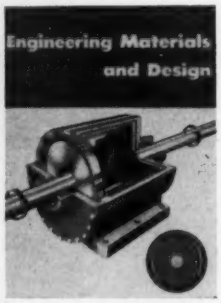


COVER: Single-stage drive system employing an internal elliptoidal-cam wave generator, a flexible spline with integral coupling to the output shaft, and a circular spline machined in the supporting case.


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## ISSUE AT A GLANCE


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**INSULATION OF WINDINGS FOR TRACTION MACHINES: PART 1** ... ... **78**
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By **W. Duckett**

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Describing a new type of constant-ratio mechanical drive.
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Survey of properties and uses.
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# Résumés

### L'ENTRAÎNEMENT HARMONIQUE

*par C. W. Musser* page 84

L'article décrit une nouvelle catégorie d'entraînements mécaniques à rapport constant pour transmissions ou conversions de mouvements. Il fournit des détails complets sur les principes de fonctionnement, les caractéristiques de performance, les divers types de dessin et les applications possibles.

### STRATIFIES AVEC REMPLISSAGE INORGANIQUE

*par R. Pemberton* page 94

On compare des stratifiés fabriqués avec des remplissages d'amiante, de verre et de métal. On étudie leurs propriétés et leurs applications. On s'occupe tout particulièrement des stratifiés préparés avec de plastiques phénolique, mélaminique époxy, silicons, polyesters et polytétrafluoréthyléniques.

### ISOLEMENT D'ENROULEMENTS POUR MACHINES TRACTRICES

*par W. Duckett* page 78

Premier d'une série de trois articles traitant respectivement des isolements catégories B, F et H. L'auteur s'occupe principalement d'une technique de presse spéciale qui permet de produire des bobines de dimensions déterminées.

### INFLUENCE DU DESSIN SUR LES TENSIONS ENGENDREES DANS LES TRAITEMENTS PAR LA CHALEUR

*par A. R. Gardner* page 100

Version abrégée d'un article expliquant comment le dessin des pièces, conjugué à la technique de refroidissement employée, peut influencer l'importance de tensions internes qui peuvent être produites durant le traitement par la chaleur, surtout durant le refroidissement.

# Kurzreferate

### HARMOMISCHER ANTRIEB

*von C. W. Musser* Seite 84

Der Artikel beschreibt eine neue Klasse eines konstanten mechanischen Antriebs für Kraftübertragungen, Winkelstellungen oder Bewegungsumwandlungen. Vollständige Einzelheiten über die Grundsätze des Betriebs, die Leistungskenndaten, alternative Konstruktionen und die möglichen Anwendungen werden ebenfalls besprochen.

### LAMINATE MIT ANORGANISCHEN FÜLLSTOFFEN

*von R. Pemberton* Seite 94

Laminate mit Asbest, Glas und Metallfüllstoffen werden einem Vergleich unterzogen und ihre Eigenschaften und Einsätze werden verglichen. Besonderes Augenmerk wird den Laminaten aus Phenolen, Melaminen, Epoxyden, Silikonen, Polyestern und PTFC Kunstharzen zugewendet.

### ISOLIERUNG DER WICKLUNGEN VON TRAKTIONSMASCHINEN

*von W. Duckett* Seite 78

Der erste einer Serie von drei Artikeln die sich mit Isolierungen der Klassen B, F und H befassen. Der Verfasser bespricht hauptsächlich ein besonderes Pressverfahren zur Herstellung von Spulen bestimmter Grössen.

### KONSTRUKTION UND DURCH WÄRMEBEHANDLUNG BEDINGTE SPANNUNGEN

*von A. G. Gardner* Seite 100

Eine kurze Version eines Artikel mit einer Besprechung der Konstruktion von Komponenten und Abschreckmethoden und deren Einfluss auf die internen Spannungen, welche bei der Wärmebehandlung auftreten können, und allgemein auf das Abschrecken zurückzuführen sind.

# Резюме

### ГАРМОНИЧЕСКАЯ ТЯГА

*С. В. Массер* стр. 84

В статье описывается новый вид механической тяги постоянного коэффициента для силовых передач, углового расставления или преобразования движения. Приводятся полные подробности его рабочего процесса, характерные черты его действия, технологические альтернативы и возможные применения.

### СЛОИСТЫЕ МАТЕРИАЛЫ С НЕОРГАНИЧЕСКИМИ ПРОКЛАДКАМИ

*Р. Пембертон* стр. 94

Сравниваются слоистые материалы, изготовленные с асбестовыми, стеклянными, и металлическими прокладками и делается обзор их свойств и применения. Особое внимание уделяется слоистым материалам из фенольной, меламиновой, эпоксидной, кремниевой, полиэстерной и политетрафлюорэтиленовой пластмассы.

### ИЗОЛЯЦИЯ ОБМОТОК ДЛЯ ДВИГАТЕЛЕЙ ТЯГИ

*В. Дакетт* стр. 78

Первая из трех статей, рассматривающих изоляцию категорий B, F и H. Внимание уделяется главным образом особой технике прессовки для производства обмоток заранее установленных размеров.

### ВЛИЯНИЕ КОНСТРУКЦИИ НА ДАВЛЕНИЕ ПРИ ОБРАБОТКЕ ПОД НАГРЕВОМ

*А. Г. Гарднер* стр. 100

Сокращенный текст статьи в которой объясняется насколько форма компонентных частей вместе с техникой закалки может влиять на об'ем всякого внутреннего давления, вызванного обработкой при нагреве, обычно во время процесса закалки.

# MATERIALS IN THE NEWS

*Monthly Digest of Materials and Design News from Home and Abroad*

## Storage Tanks in Reinforced Plastics

IN THE MANUFACTURE of storage tanks for chemical and allied plant, conventional materials such as mild steel are often use less for long-term installation, due to the corrosive nature o, the liquids involved. With this in mind, Bristol Aeroplane Plastics Ltd. have developed a reinforced plastics tank incorporating a number of features which greatly increase corrosion resistance and useful life.

Originally developed for the United Kingdom Atomic Energy Research Establishment at Harwell, a number of these tanks are now installed to handle radio-active effluent. Reinforced plastics made from specially developed resins were chosen for this particular role, where deterioration of the material or structure must be avoided, and it has proved to be the only satisfactory material capable of withstanding the resultant chemical action.

In addition, the smooth, continuous, jointless faces of the tanks eliminate weak points where, under the high stresses imposed by large quantities of liquid, jointed areas would present a hazard. The smooth internal faces also guard against pockets of effluent becoming trapped and remaining active when the tanks are drained.

Specialised design work was necessary to meet all requirements, and this resulted in a tank comprising a double-skin, foam-filled structure capable of overcoming large deflections under heavy loads. This method also produced the lightest tank for a given capacity, and opened the way for very large storage tanks which are strong, yet light enough to make handling a simple procedure compared with that required for equivalent sized metal tanks.

The use of reinforced plastics for chemical storage tanks is but one of a vast number of applications which will, during the next few years, play an increasingly important part in plant installation in the chemical, atomic and general industries.

## New British Computing System

AN ADVANCED NEW BRITISH COMPUTING TECHNIQUE was discussed in a lecture to an international audience of scientists, industrial chemists and control engineers, at a recent conference in Brussels. This technique, which combines the advantages of analogue computation with the extra facility of digital data storage, enables certain calculations to be done with simpler installations and at a lower cost than is possible with conventional computers. The technique is used in the Redifon Analogue-Digital Computing System, or RADIC, introduced by Redifon Ltd.

The addition of a magnetic-tape digital data store to a general-purpose analogue computer greatly increases the range of possib' applications for the computer. Certain computation problems in the design of chemical plant can be simplified by using the digital storage system to hold partial results of calculations.

The Redifon system is particularly suitable for calculations where frequent changes of input data have to be made to keep track of a changing situation or to find optimum conditions. For the design of complex automatic control systems, it can be used as an inexpensive "electronic model" on which preliminary experiments can be carried out. The Admiralty, for example, has ordered one version for use as a simulator in the design of naval control equipment and instrumentation.

Basically the system is an expandable d.c. analogue computing equipment, with digital input, output and control facilities and a magnetic-tape digital storage unit. Extra computing elements can be added easily and at minimum cost—in most cases without enlarging the cabinet.

## Liquid Metal Fuel Cell

A LIQUID METAL FUEL CELL that has been tested in a proof-of-principle research may point the way to a powerful yet compact electrical system for space age applications. Development of this cell was recently reported by scientists at the Allison Division of General Motors. Because it has no moving parts, such a system may fulfill the extremely high reliability standards required for space equipment.

Although fuel cells for converting chemical energy directly into electrical energy have long been studied, this invention is believed to be the first demonstration of a thermally regenerative device.

Improved versions of the small laboratory model already under development are hoped, in their final form, to be as much as ten times smaller than other types of fuel cells producing equivalent electrical output. These liquid metal fuel cells could operate in conjunction with a heat source, such as a mobile compact nuclear reactor.

Using the nuclear conversion process under development at Allison, a reactor would be cooled with liquid metals, through providing a heat source for the regenerative fuel cell. Heating would cause the metals to separate at their various boiling temperatures. Their recombination would result in the creation of an electrical current which would eventually provide electric power for submarines, remote military bases, barge-borne emergency power sources, and the electro-jet propulsion systems of the future.

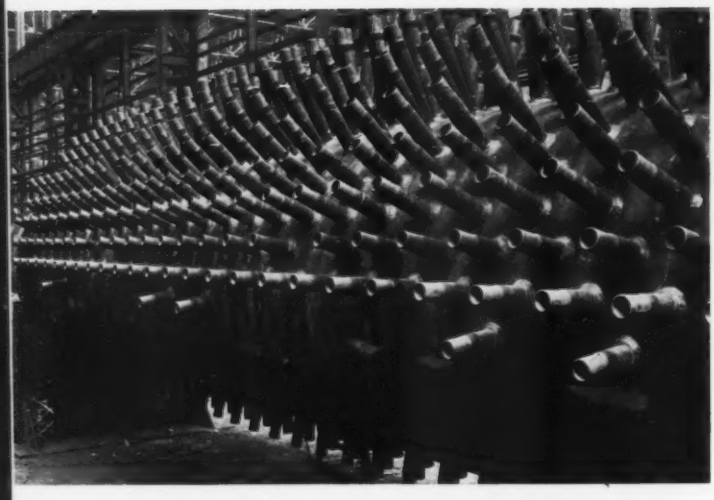
## Flame Retardant Treatments

EVERY YEAR THE COST OF FIRES, both in lives and money, continues to rise, and at the same time there has been in the past ten years a growing tendency to avoid the use of plaster on walls and ceilings and to use instead fibre-insulation board, hardboard and other building boards. These boards have tremendous advantages, being comparatively inexpensive and easy to use, but the majority of such materials have the prime disadvantage of being readily inflammable. The Thermal Insulation (Industrial Buildings) Act 1957 gives the Minister of Power the authority to reject plans of proposed industrial buildings, unless such plans show that the materials used would conform to a prescribed standard of resistance to the spread of flame. This standard of resistance is Class I of BS476, Pt. I ("Surface spread of flame test"). These regulations are expected to be extended soon to cover existing buildings, but even with new installations it is cheaper to apply a flame retardant coating to an inflammable board than to use the relatively expensive, inherently non-inflammable boards.

With this in mind the Pearl Varnish Co. Ltd., has developed a flame retardant paint known as Trerock, which can be used like a normal paint during decoration. This paint is made in a wide range of colours so that no further finishing is required. It consists of a combination of inert chemicals and pigments which are bound together with an emulsion medium. When a board painted with this type of coating is exposed to heat, the constituents of the paint fuse together forming an impervious film over the surface of the board. In this way the inflammable gases contained in the board are prevented from escaping, and at the same time atmospheric oxygen is denied access to the board, thus preventing ignition. In addition, certain endothermic reactions take place so that heat is absorbed from the source, and this helps to some extent to keep the temperature down and so reduce the intensity of the fire. A further advantage claimed for this material is that the emulsion medium protects the paint film from the effects of moisture, so that its flame retardant properties are not affected by the passage of time.

# PICTURE NEWS

## IN THE WORLD OF MATERIALS & DESIGN

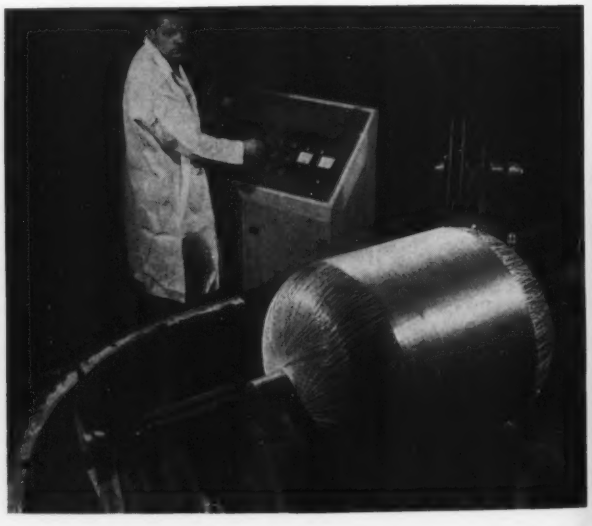


**BOILER BRISTLES**

In modern high-duty water-tube boiler construction, it is now the practice for the boiler tubes to be welded to short stubs which form an integral part of the boiler drums. Designed by G. A. Harvey & Co. (London) Ltd., the drums shown above are lagged and preheated to 150 deg. C. before welding.

**ISOTOPES IN INDUSTRY**

Production of electricity is not the only useful application of atomic energy, for by-products in the form of radioisotopes play an important role in many industries, including engineering. The U.K.A.E.A. photograph above, shown recently at an exhibition by Ilford Ltd., illustrates the use of a thickness gauge to measure pipework.



**PLASTICS PRESSURE VESSEL**

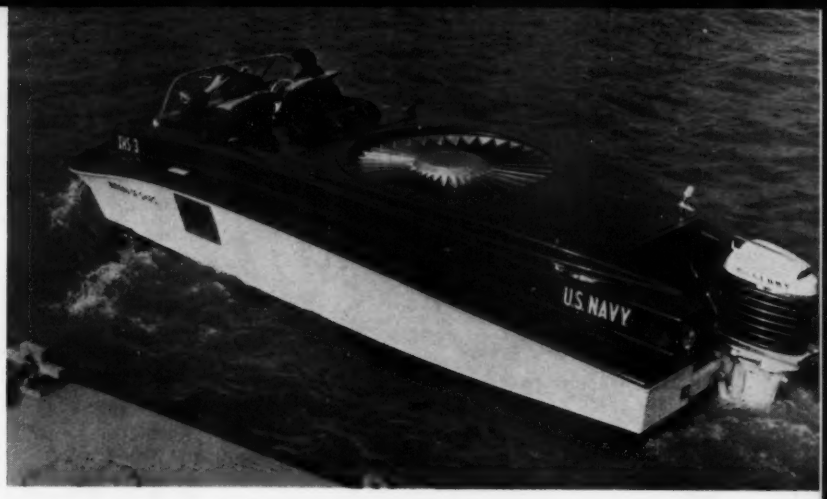
Unidirectional strengths up to 340,000 p.s.i. are claimed by the Tapco Group of Thompson Ramo Woolbridge Inc., U.S.A., for a fibre-resin system produced by a special filament winding technique. A plastics pressure vessel is seen above on the helical winding machine.

**MODERN MATERIAL AIDS DESIGN**

This selector switch unit (*left*) for a 500-kV. high-speed resistor on-load tap changer is being manufactured at the English Electric new transformer works. The use of cast epoxy resin insulation has enabled the creepage path between contacts to be considerably increased, and at the same time the insulation is resistant to tracking.

**PLASTICS RIDES ON AIR**

This experimental Hydroskimmer developed by Bell Aerosystems Co. has a glass-reinforced polyester hull, and cruises over the water on a cushion of air which is driven under the hull by a large fan. The Hetron resin used for the hull is a product of the Hooker Chemical Corp., New York, and combines high strength with fire retardance.

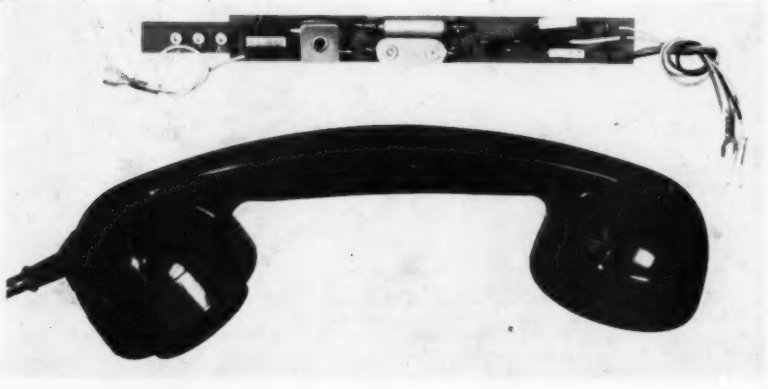


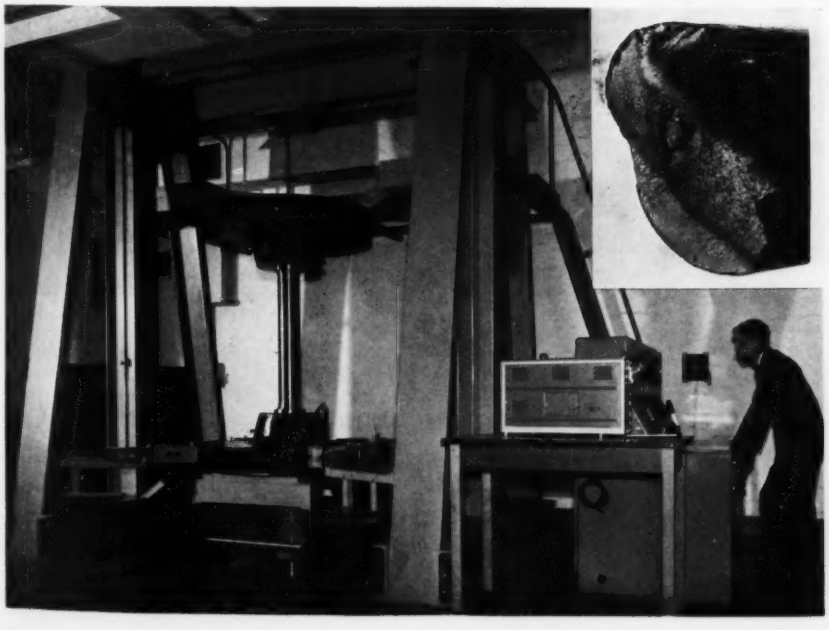
**MODERN DESIGN SEWING MACHINE**

The general design of this Jones Sewing Machine Co. Ltd. product is intended to meet the most exacting demands for modern streamlining, and the machine is most attractive in its finish. Its beauty is enhanced by pastel colours in keeping with the modern trend.

**AMPLIFIED HANDSET**

This telephone handset, manufactured by Ericsson Telephones Ltd., provides amplified reception for the deaf. It contains a transistor amplifier powered from the telephone line, and has a gain of up to 20 decibels adjustable by a miniature volume control in the handset. No modification to the telephone circuit is required, and the output is limited to prevent acoustic shock to the user.



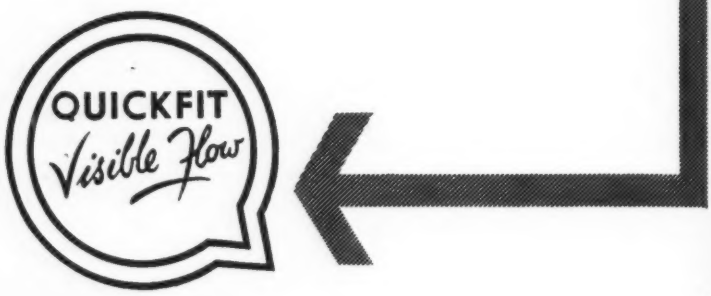


**AXLE FATIGUE MACHINE**

London Transport's new research laboratory, at Chiswick, houses this resonant fatigue testing machine, which enables axle-sized steel specimens to be subjected to rotating bending stresses such as are encountered in service. Inset is shown a tested specimen broken open by static bending to expose the fatigue fractures produced on the machine.

# PRICES UNCHANGED

for




# GLASS PLANT & PIPELINE

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## P.v.c. Pump for New Braille Printing

UP TO RECENTLY, Braille printing for the blind was formed by embossing characters on a strong paper. This method had certain disadvantages in printing, due to the care which had to be taken in forming the characters to avoid over-distortion of the paper fibres during embossing. In addition, the embossing method suffered from the wear on the characters during touch reading by the blind.

The Royal National Institute for the Blind have therefore devised a machine which will deposit the characters more firmly and permanently on the paper. A special p.v.c. plastics is used for this purpose. The Braille is perforated on metal plates for mounting on a rotary cylinder, and the plastics is then forced through the perforations to deposit the characters in the form of minute beads of hard wearing material on the paper. A lighter weight of paper can be used, the Braille can be more easily and quickly read by touch, and the characters are not so easily damaged.

In perfecting the machine, it was necessary for the Institute to simplify operation to form a pattern of repetition easily assimilated in practice. One of the problems was associated with the handling of the p.v.c. plastics. A pump was required to withdraw the plastics from open-topped 5-gall. containers, and discharge it to a hopper feed to the machine. The pump had to be self-priming, with a powerful suction through a short length of flexible suction hose, which could be easily inserted into the drum. The extreme viscosity of the plastics material presented a difficult pumping problem, and a CD30R2 Mono pump was offered to the Institute for trial purposes. An operating speed of 130 r.p.m. was recommended, and following various tests carried out by the Institute, the Mono pump was found to fulfil the required conditions.

## A New Reinforcing Material

GLASS FIBRE is well established as a reinforcement for plastics, but in certain applications its supremacy may be challenged by a new material recently introduced by S. Hubbard Ltd. The basic material is felt, which has been chemically hardened and then impregnated with a polyester resin to form a hard yet resilient material.

With their experience of hat making, the company are commercially using this material in the first instance for safety helmets, the first series being designed for motor cyclists and scooter riders, and claimed to be well within the rigid specifica- laid down by British Standards.

The material is easily moulded with the minimum of special equipment and, being completely impervious to water, could find a use for shaped engineering components. A further successful development is the production of this material with a glossy surface, which makes it suitable as a substitute for porcelain or vinyl wall and floor tiles.

## High-density Ceramics

A RADICALLY NEW PROCESS for producing high-density pressure fired ceramics with 80 per cent fewer voids or air pockets than in conventional ferro-electric ceramics has recently been developed by the American company, Gulton Industries Inc., who recently announced the formation of a British subsidiary, Gulton Industries (Britain) Ltd.

The new high-density ceramic, which is known as Glennite HT-8, is made by the application of extremely high pressure during firing from three axial directions to supply a net compacting force. These new pressure firing techniques are said to be a significant advance in the technology of manufacturing high-density ferro-electric and piezo-electric ceramics.

The elimination of voids is claimed to result in higher piezo-electric sensitivity, higher dielectric constant, lower dielectric and acoustic loss, and a stronger and more durable product with 100 per cent improvement in temperature stability.

In addition the new technique produces a ceramic with highly uniform grain size, with a corresponding improvement in the consistency of the electro-mechanical properties. This technique also makes it possible to make larger one-piece ceramic units. One-piece transducer discs as large as 20 in. dia. can be made by this process, as against discs of only 6 in. dia. which are possible with conventional techniques. The new ceramics are now being used in sonar and ultrasonic processing and electronic components.

With the use of the new pressure fired process, densities greater than 8.0 have been attained in comparison with the 7.5 maximum densities previously achieved by the industry in the production of lead zirconate-titanate.

Another important aspect of the new production process is that hyper-pure raw materials may now be used in the fabrication of ceramics without the use of fluxing or glass-forming agents. For example, high-density ceramic produced by this method from hyper-pure barium titanate has a specific dielectric constant of 4,300 at room temperature, as against 1,500 for a conventional barium titanate ceramic.

X-ray photographs of Glennite HT-8 show only a very small well-distributed void pattern, and give the ceramic uniform properties as a transducer.

Another interesting development is a technique which enables ceramics to be produced in thin film having a thickness of only half the wavelength of green light. This film is flexible, on account of its extreme thinness, and it can be used for the manufacture of capacitors having a high degree of stability. A film of glass fused to the ceramic coats the capacitor, and protects it from ambient atmospheres, at the same time permitting operation up to 150 deg. C.

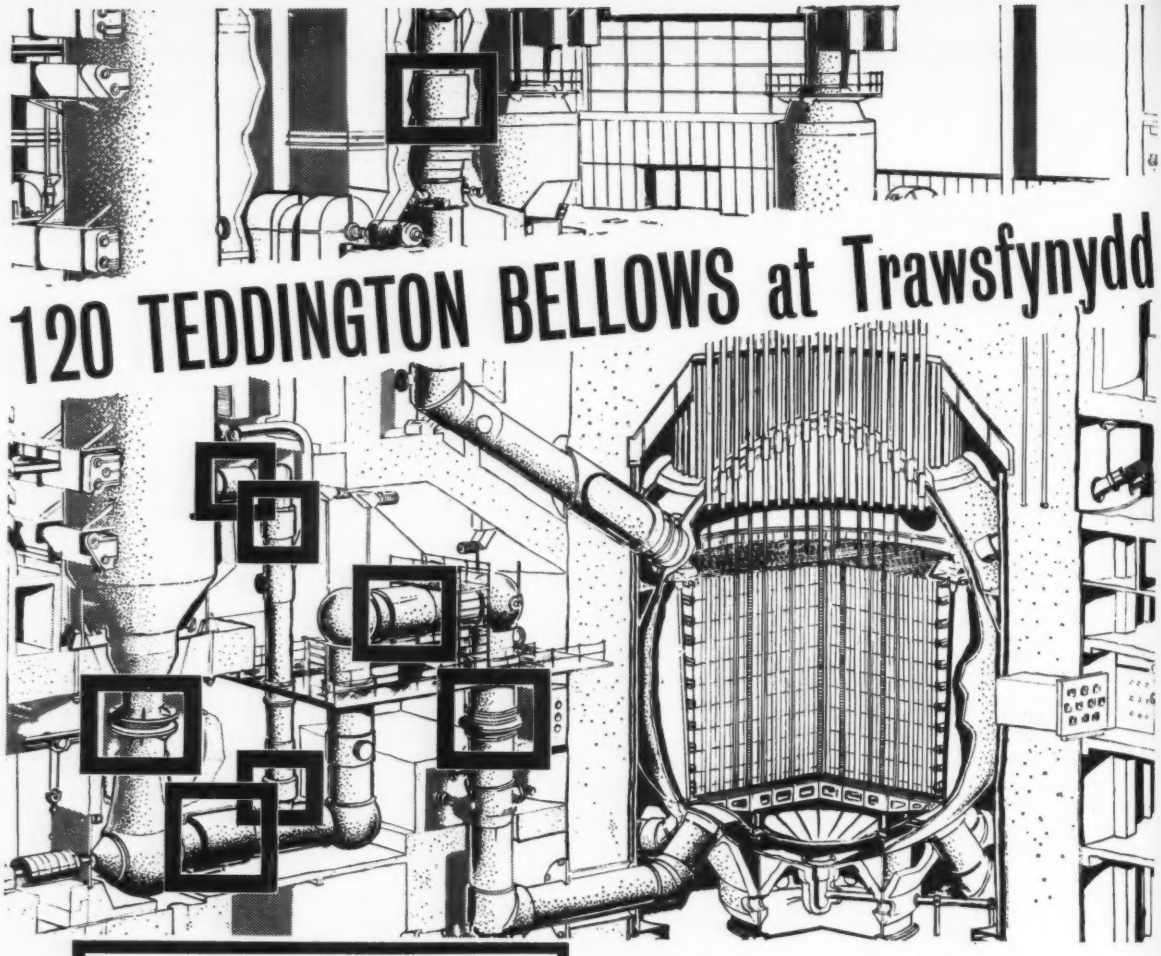
## Plastics Pipe Made on Automatic Machine

THE HIGH STRENGTH AND CORROSION RESISTANCE of reinforced epoxy resins has led to an interesting development in the field of high pressure piping. This process is known as the Epoch Piping System, and has been developed by Bristol Aeroplane Plastics Ltd. The basic idea of a reinforced plastics pipe is not new, but the Epoch Pipe is now being produced in quantity by an automatic winding plant capable of producing at a high rate, and controlled by an electronic console through a punched card system. An advantage claimed for this process is that close control can be maintained over the resin and impregnated fibres to give a consistent and uniform product. This is said to overcome one of the greatest difficulties in applying plastics to engineering—that of unreliable quality. Fittings are also available in the same material.

THE load-carrying structure of the pipe comprises a number of sheaths or complete layers of low alkali glass filaments, thoroughly impregnated and bonded with thermosetting epoxide resin. The helix angles at which the glass filaments in any one layer run with respect to those in other layers are proved by mathematical analysis and experiment to give a pipe of minimum strain over a wide range of combined hoop and beam loadings, rather than a pipe of maximum strength under any one particular loading, e.g. hoop loading twice the beam loading as in a closed pressure vessel. It is thus a long-life pipe for general service use, rather than a special purpose pipe which is only satisfactory under a limited set of ideal conditions.

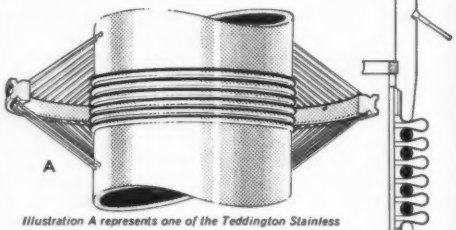
To provide the highest possible resistance to chemical attack, and to achieve a high measure of abrasion and damage resistance, both the inside and outside of the pipe walls are reinforced with woven acrylic fibre.

The control desk of the Bristol automatic pipe-making plant.



# 120 TEDDINGTON BELLOWS at Trawsfynydd

By courtesy of 'NUCLEAR POWER'



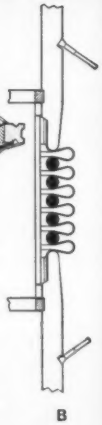




*Illustration A represents one of the Teddington Stainless Steel Bellows supplied to Trawsfynydd with a novel form of restraint designed by Richardsons, Westgarth & Co. Ltd. (a member of Atomic Power Constructions Ltd.). This avoids the use of highly stressed hinge pins and permits a complete gimbal movement.*

*Illustration B indicates a section of Teddington Bellows, showing the restraining rings for extra strength which are a feature of this bellows design.*

**NO LESS THAN 84 BELLOWS 66" diameter and 36 BELLOWS 42" diameter, all of butt-welded stainless steel manufacture, are being fitted at Trawsfynydd to take up movement in the $CO_2$ cooling gas ducts.**

**Teddington secured this order only after many exhaustive tests including an accelerated life test equivalent to 20 years full operation. In addition, the larger size bellows were subjected to over-pressure tests of 1680 p.s.i.g. without developing a leak. Wherever pipe-work is subjected to vibration and movement in any direction owing to conditions of temperature and pressure, a Teddington bellows with a suitable end fitting will solve the problem. Write for full details of our range.**

## TEDDINGTON AIRCRAFT CONTROLS LIMITED

**(INDUSTRIAL BELLOWS DIVISION),**

**AMMANFORD, CARMS.**

*Made under Licence from the Solar Aircraft Co. California, U.S.A.*

## New Hot-dimpling Machine

THE ADVANTAGES OF HOT DIMPLING to provide crack-free dimples for flush rivets or fastenings are well known, particularly by the aircraft industry, and to exploit this process as widely as possible a fully automatic machine has been designed, developed and manufactured by Short Brothers & Harland Ltd., of Belfast. The necessary precise operation of the dies is achieved by a pneumatic-hydraulic system; the proprietary equipment selected for this purpose was manufactured by Maxam Power Ltd., a company within the Holman Group, of Camborne, Cornwall.

Accurate temperature control was of primary importance, and for this to be effective a fully automatic operating cycle would have to be incorporated, to reduce the possibility of human error to an absolute minimum.

Preliminary trials were carried out with a manually controlled unit, and with a portable tool incorporating automatic control. The successful outcome of these tests led to the design and development of the final fully automatic production machine. This consists basically of robust castings forming a yoke which supports the male and female dies, the latter being mounted directly on the lower jaw. The upper die, which is movable, is mounted on a hydraulic ram which is operated by an electrically controlled pneumatic-hydraulic system. All control and setting arrangements are built into the main castings, and all components are readily accessible for setting or maintenance.

The dies are electrically heated, temperatures being controlled by a built-in thermocouple in conjunction with a specially designed electronic system. This unit also controls the Maxam solenoid-operated pneumatic valves which function, in accordance with the temperature control, to exert the forming pressure in two stages.

The control unit prevents initiation of the operating sequence until the dies are at the correct preset temperature, as indicated by a green light on the panel. The operator then positions the component on the tool by means of a predrilled hole, and presses the foot switch. From this point onward the whole cycle is entirely automatic.

A unique feature of the design is that a dimple cannot be completed until the metal has been heated to the correct temperature to ensure the desired ductile state. This is achieved by introducing two distinct phases of operation, which are completed at different pressures. The first stage, which is initiated by the operator, brings the dies into contact with the component at a preset pressure, which is adjusted in accordance with the thickness and nature of the material. When the metal has reached a predetermined stage of deformation under this initial pressure and the heat supplied by the dies, the pneumatic circuit is changed over so that the hydraulic pressure on the ram is increased considerably for the final stage of dimpling and is maintained at this setting for a controlled period. This variation in the applied pressure is achieved by the normal operation of a standard Maxam air-hydraulic intensifier unit, the actual ratio in this instance being 8:1. Much higher ratios of intensification are, of course, possible by appropriate adjustment of the piston diameters in the Maxam unit.

The control circuit is completely interlocked, with appropriate relays incorporated so that, once the cycle of operations is initiated by the operator, control passes entirely to the automatic system and no action by the operator can influence the completion of the process in accordance with the preset sequence. In this way consistency of results is ensured, which is beyond the influence of human fallibility.

*THE MARCH ISSUE . . .*

of *Engineering Materials and Design* will include the following main features:

**Insulation of Windings for Traction Machines: Part 2**
Dealing mainly with a special technique for the production of coils to a predetermined size (using Class F insulation).

**The Harmonic Drive: Part 2**
Examples of various applications of this new device.

**Survey of Hydraulic Actuators**

## Electronics Help to Keep the Heart Beating

THE LUCAS ORGANISATION is now associated with an important development in the medical field. This concerns improvements to the Cardiac Pacemaker, developed at the Queen Elizabeth Hospital in Birmingham. The Pacemaker is an artificial method of initiating the heart beat in patients who are suffering from a condition known as "heartblock." This condition can be fatal or result in frequent loss of consciousness.

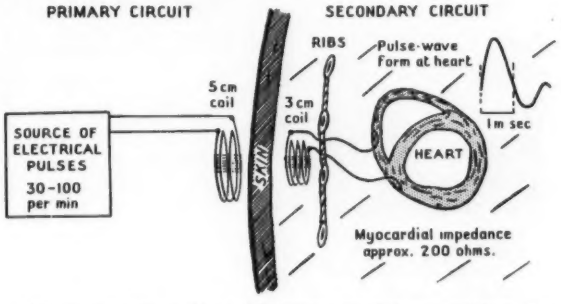



Diagram of the method of inductive coupled pacemaking.

Past methods of providing the pulses to the heart muscle were superseded by a portable system in which a pulse from a miniature transistorised generator is passed inductively (i.e. from one coil to another coil in close proximity although not actually touching) from a primary coil placed outside the body, to a secondary coil about the size of half-crown placed below the skin, and thence by wires to the muscle.

Investigations by Lucas engineers have resulted in a lightweight Cardiac Pacemaker incorporating several improvements. The secondary coil (within the patient's body) is now insulated with a material more resistant to the effects of body fluid. The means for producing the "pulse" (i.e. oscillator) can be more easily carried around and controlled by the patient due to the use of the newly developed Lucas transistors, and a printed circuit incorporated in the pulse generator.

A great deal of thought is being given to the question of reducing even more the weight of the equipment concerned, and to this end Lucas are investigating the design of suitable batteries and further miniaturisation of equipment.

## Design for Welding in Thermoplastics

OF THE MANY PROCESSES USED in the fabrication of thermoplastics, the welding processes are now of paramount importance, and with the increasing use of these materials in practically every industry, the Institute of Welding has decided that there is now need for a special course on the correct approach to design for welding.

In order that designers may be provided with the information necessary for the design of efficient structures in thermoplastics, a short course has been planned to cover the basic materials and their properties, the welding processes, and the principles of good design for welding.

The Institute is being assisted in the organisation of this course by the Joint Committee on the Welding of Thermoplastics, which is sponsored by the Plastics Institute, the British Plastics Federation, and the Institute of Welding.

The fee for this course is £11, but members of the Institute and the employees of Industrial Corporate Members will be admitted at the reduced rate of £8. The course will be held on January 30-31, and the lectures will include: "Materials"; "Considerations at the Drawing Board Stage"; "Design for Welding in Rigid P.v.c."; "Design for Welding in Flexible P.v.c."; and "Design for Welding in Polythene."

This is the administration centre of the world's first electronic telephone central office, now serving a group of customers in Morris, Illinois, U.S.A. A paper describing this telephone exchange was given at the Conference on Electronic Telephone Exchanges, by representatives of Bell Telephone Laboratories Inc.

## Electronic Telephone Exchanges

TELECOMMUNICATION EXPERTS from many countries recently attended a Conference on Electronic Telephone Exchanges, at the Institution of Electrical Engineers, where they discussed the progress so far made in designing a public service electronic telephone exchange in various countries.

The British Post Office has already used electronic equipment to register and control the setting up of subscribers calls. The first electronic director went into public service at Richmond exchange in the London Area in 1952, and continues to give extremely reliable service. G.R.A.C.E., the subscriber trunk dialling equipment at Bristol opened by Her Majesty the Queen in December 1958, uses electronic equipment. A magnetic drum has also been used as a director at Lee Green exchange in London.

In London and other large cities equipped with director exchanges which are to be provided with Subscriber Trunk Dialling next year, G.R.A.C.E. will use a magnetic drum to control routeing and charging. The success of this electronic equipment in the control and setting up of telephone calls led the British Post Office, in co-operation with the manufacturers of Exchange equipment, jointly to examine the problems of designing and building an electronic exchange. As a result a model electronic exchange was installed at the Post Office Research Station, Dollis Hill.

Many problems have had to be overcome, and each manufacturer of Post Office exchange equipment has worked on a separate section of the model exchange to ensure that the best specialised knowledge could be applied to design and development. It is hoped that when these exchanges become a practical proposition they will provide greater flexibility to the telephone service and, because moving parts will largely be eliminated, provide greater reliability and economy both in the size of buildings needed for exchanges and in maintenance.

On completion of the experiments with the model electronic exchange—probably in the next year or so—equipment for about 1000 lines will be installed as a public exchange at Highgate Wood, in North London. When this has been done, extensive evaluation trials of the public use of the electronic exchange will be made, and it is only when the engineers decide that a fully reliable service can be provided that the Post Office will change over from the conventional electro-mechanical exchange.

During the past ten years electronics has been applied to other aspects of telecommunications, e.g. it has been used to increase the number of simultaneous conversations over the Transatlantic Telephone cable.

## Plastteknik 1960

THE SWEDISH PLASTICS FEDERATION TECHNICAL CONFERENCE, Plastteknik, has always attracted a large number of overseas lecturers and visitors. As usual the 1960 Conference, attended by over 600 delegates, was held in Stockholm, this time from November 21-24. It is difficult to do full justice in a few words to the sixty-five lectures which were given in three concurrent sessions, and which covered the whole field of plastics technology, as well as the influence of the European Market Integration on commercial aspects of the plastics industry.

It is not surprising that the majority of papers were devoted to thermoplastic materials, which still dominate the industry. More and more attention is being paid to the engineering properties of p.v.c. and polyethylene; stress cracking and weld strength of these materials moulded by various techniques were discussed in some detail. There were also some interesting contributions on newer types of p.v.c. plastisols, ABS sheet and polypropylene. The applications of polyurethane foams and the preparation of phenolic foams provided some stimulating thoughts from experts in this field.

One section of the conference was concerned with glass fibre reinforced plastics. Here again the papers were mainly of a practical nature, and concerned the development of better methods of quality control based on: practical experience; the performance of various peroxide catalysts for curing polyesters; the development of polyester dough moulding compounds; and on improved engineering properties of glass fibre reinforced plastics in general.

The ever growing importance of p.v.c. stabilisation, and in fact of p.v.c. as a whole, was reflected in a large number of papers on this subject. Although there is an increased tendency for p.v.c. to be used in buildings and for external applications, the way in which various p.v.c. stabilisers act is still not fully understood, and there is large scope for further research.

Vacuum forming of thermoplastic sheet, which is steadily gaining in popularity, was dealt with at length. Some of the newer interesting materials such as polycarbonates, water soluble resins for stoving paint formulations or the industrial coating of steel, ditridecyl phthalate as a new p.v.c. plasticiser, new types of high impact p.v.c. and acetal resins, were described and provided a useful exchange of information about the different applications these materials find in various countries.

## Intercommunication System for Pressurized Suits

THE PROBLEM OF DESIGNING an intercommunication system suitable for working with pressurized suits has always been one of considerable magnitude, increasing in importance in more recent years. It is with this in mind that Spembly Ltd. have introduced their transistorised intercommunication system suitable for working with their range of pressurized suits.

This intercommunication system was primarily designed for the U.K.A.E.A., who stressed the importance of ruggedness and reliability. The major problem of background air noise has been reduced considerably by incorporating a noise limiter in the personal receiver. An air filter to muffle the air supply has also helped to overcome a large amount of background air noise.

The control console, designated the "master," is capable of supplying up to ten "slaves." Direct communication between any slave and master is possible at all times without the operation of any external control. Similarly any slave can be in direct communication with any other slave.

One unique feature of the equipment is the plastics coating of the personal receivers, which gives protection against any accidental knocks. A second feature is the small size of the personal set—it fits easily into most pockets.

**FOR FURTHER INFORMATION:—**

Bristol Aeroplane Plastics Ltd., Filton House, Bristol.
Redifon Ltd., Computer Department, Gatwick Road, Crawley, Sussex.
Allison Division of General Motors, Indianapolis, Indiana.
Pearl Varnish Co. Ltd., Treforest Industrial Estate, Pontypridd, Glamorgan, South Wales.
Mono Pump Ltd., Mono House, Sekforde Street, Clerkenwell Green, London, E.C.1.
S. Hubbard Ltd., Luton.
Gulton Industries (Britain) Ltd., 9 Drapers Gardens, London, E.C.2.
Joseph Lucas Ltd., Sales Engineering Department, Great King Street, Birmingham, 19.
The Institute of Welding, 54 Princes Gate, London, S.W.7.
General Post Office, Headquarters Building, St. Martins-le-Grand, London, E.C.1.
Spembly Ltd., Chatham, Kent.

# IS THE ENGINEER UNDERPAID?

THE Report of the Royal Commission on Doctors' and Dentists' Remuneration, which was published during 1960, does not appear, on the face of it, to be of much concern to the average engineer. However, as part of the work in assessing the position of the medical man in relation to other professions, the Commission studied the salaries of engineers by means of a joint survey with the Engineers' Guild. An analysis of some of the figures has been made by the Engineers' Guild, suggesting that not only are the salaries of professional engineers sadly inadequate, but that they also compare unfavourably with those of other professional men.

PROFESSOR JEWKES, professor of economic organisation at Oxford university, comments that there is, of course, no unchallenged body of principles to indicate what is the proper level of earnings in any profession, nor what should be the correct relationships between the earnings in different professions. On what basis, therefore, can the salaries of professional engineers be computed? One might suggest, for instance, length of training, degree or responsibility towards human life, and, as Professor Jewkes said, the law of supply and demand.

Responsibility for human life, however, may be invested to a far greater extent in an engineer than a doctor. For example, the engineer may be responsible for up to 100 travellers in a transport plane, whereas an error on the part of a doctor is likely to affect only a single person.

The origin of the difference in pay between an engineer and a doctor is likely to be found in a social sense stemming from the early days of engineering, when the work was manual, whereas to be a doctor required both money and social standing.

While social differences will, and should of course exist, the professional engineer of today is an entirely different person to the engineer of the past, and a new datum should be provided to give him his correct status, and a commensurate salary. The general public should be given an assurance that our leading engineers will not be tempted by attractive offers to take their skill to other countries.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# DON'T SHOOT THE DESIGNER . . .

RECESSION and redundancy are words on everyone's lips at the present time, particularly in relation to the motor industry, and much of the blame is being put on design. The motoring Press is full of correspondence alleging that British cars are badly designed, badly made and badly finished; the adherents of vehicles like the Volkswagen "beetle" proclaim the superiority of foreign cars in nearly every possible respect. In particular the word "shoddy" has been used to describe the British car of 1960, and now that the motor industry has passed from its most prosperous era to a period of reduced output, there are bound to be many people who put the blame on quality. Whether they are right is not primarily our concern, but the position of the designer in times of recession most certainly is, not only as applied to the motor industry, but in all engineering industries which have ups and downs.

Many critics of the motor industry illustrate our "backward" designs by giving examples of foreign cars with aluminium engines, air-cooled cylinders and all-independent suspension, but these criticisms often come from the relatively thin ranks of the motor-car enthusiasts, who represent a specialised and rather small section of the motoring public. Not every car owner wants or needs disc brakes and sports-car cornering, but everyone wants value for money and reliability. Both of these factors should be determined by design, but unfortunately this rarely seems to be the case, because so many companies keep their designers in isolation, away from service department influences but under strong pressure from a production and cost-minded management.

In matters of technical progress Britain has much to be proud of in the field of automotive engineering. As far back as 1934 an aluminium crankcase was a feature of the Lanchester, and clutchless gear-changing was available on the Sunbeam Snipe and the Morris Oxford Six. In recent years British cars have dominated Grand Prix racing, and many British components such as tyres and bearings have been used on foreign racing cars, so that our designers are certainly not backward where purely technical development is concerned. In overall design the Triumph Herald and B.M.C. Mini-Se7en both represent a bold approach in the small-car field. It is a pity, however, that so many customers running small British cars find cause to complain of irritating faults attributed to shoddy manufacture.

Among larger cars the situation is worse, because even the designs are said to be out-dated. This raises the question of what is the best time to develop new designs; unfortunately, many firms seem to be too busy to do this during prosperous periods, and it is difficult to persuade them to redesign a product which is selling well. Naturally during a recession there is less money available for building and testing prototypes, and whereas an increase in business is usually a slow process, slack periods develop very quickly, so that there is no time to redesign once the downwards trend is evident. This situation puts the designer in a difficult position, for he is either frustrated at lack of interest in new ideas, or rushed off his feet so that he cannot give of his best.

If and when the designer is given his true place in industry, perhaps he will be able to exert more influence on the production departments to execute his ideas more thoroughly, and to ensure that the product which reaches the customer does justice to the design. Meanwhile, may we make one suggestion to those responsible for motor-car design—that they should follow the example of the Swedish car manufacturers, who pay a great deal of attention to safety, particularly as regards internal design of cars with the object of avoiding unnecessary injuries to the occupants in the event of an accident.

The Editor

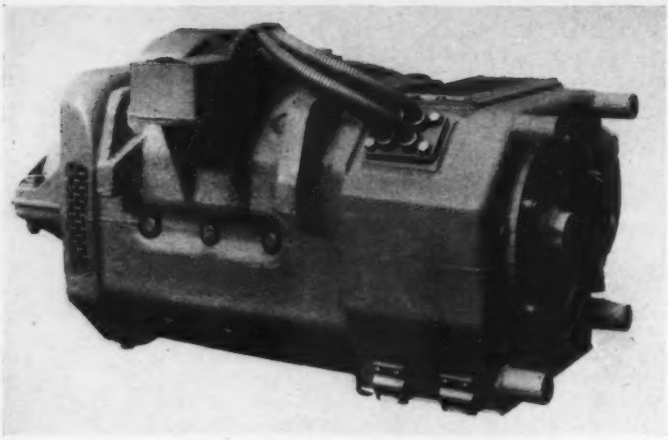


Fig. 1. G.E.C. type LT.III traction motor for London Transport Executive; view on suspension nose side.

# PART I INSULATION OF WINDINGS FOR TRACTION MACHINES

*This article is the first of a series of three dealing respectively with Class B, F and H insulation. In particular, the author describes a special processing technique for making coils to a predetermined size*

by W. DUCKETT*

ELECTRICAL machines used for traction purposes must combine a high degree of performance with ruggedness and reliability. To a large extent, the success of a particular design relies on the insulation of the windings, but in order to obtain a high output the volume and weight of the insulation used must be reduced to the absolute minimum. The mechanical and electrical properties must also be of the highest possible quality, and the type and amount of insulation used must be accurately determined so that space is not wasted, and at the same time the reliability of the equipment not jeopardised.

Unfortunately, the design of the insulation cannot be drawn up from purely scientific data, because the properties of the materials used are to a great extent dependent on the methods of manufacture. Furthermore, the design must be influenced considerably by these methods of manufacture. The information given in this article is intended as a practical guide to designers, and is based on many years' experience of workshop practice and service performance of traction machines.

Three types of insulation are at present in use for traction machine, depending on the permissible temperature rise. According to BS 2757: 1956, these are: Class B, 130 deg. C.; Class F, 155 deg. C.; and Class H, 180 deg. C.

The first of the following articles deals exclusively with Class B insulation, which has been successfully used for nearly twenty-five years on the London Transport Executive underground motors.

* Prior to his retirement, the author was insulation engineer on traction design at Crompton Parkinson (Chelmsford) Ltd.

## CLASS B INSULATION

### Heavy-duty Field Coils

Both main and interpole coils are usually made up of two tiers (see Fig. 2) and it is preferable for economy and ease of manufacture to design the main field coils of even tier construction, i.e., the same number of turns on top and

*Table 1. Field coil insulation*

| | | Series windings |
|---|---|---|
| Interturn insulation | | Asbestos paper or mica combination<br>Large machines — A<br>Small machines — B |
| Insulation between tiers | | Mica combination — C |
| Insulation to earth | Up to 750 volts | Single layer mica combination<br>Large machines — D<br>Small machines — E |
| | 750-1,500 volts | Twolayers mica combination<br>Large machines — D<br>Small machines — E |
| | Over 1,500 volts | Three layers mica combination<br>Large machines — D<br>Small machines — E |

bottom tiers. However, when the overall height of a complete machine is limited, as in the case of a traction motor, by the clearance needed between the underside of the magnet frame and the running rail, or in the case of a vehicle motor by the road clearance, the main field coils must be as shallow as possible. In this case, therefore, they should be of uneven tier construction, the winding having more turns on the bottom tier.

The windings are built up from soft double annealed copper strip (BS 1432: 1953), which should be provided with radiused edges to prevent possible damage to the interturn insulation during the winding operation. The radius varies according to the thickness of the strip, ranging from semi-circular up to 0·03-in. strip, 0·015-in. radius between 0·03 and 0·06-in. strip, and increasing to 0·03-in. radius on strips 0·06 in. and over.

Insulation of the coils should be considered in three stages: (1) interturn insulation; (2) insulation between tiers; and (3) insulation to earth. Recommended materials for these stages are given in Table 1.

The interturn insulation is applied between the conductors during winding, and it should be cut to a width sufficiently large to overlap slightly the edges of the copper strip. When applying this interleaf, it is good practice to attach it to the conductor at intervals by an adhesive such as Chatterton compound, to avoid displacement of the insulation during the winding operation. The thickness of insulation applied between turns and between tiers is determined mainly by mechanical considerations, and is independent of voltage. However, insulation to earth varies according to the motor voltage, one half-lap layer being adequate up to 750 volts, and two half-lap layers up to 1,500 volts. Machines above 1,500 volts are seldom made in the U.K., but for continental voltages, particularly in Italy, three half-lap layers would be required.

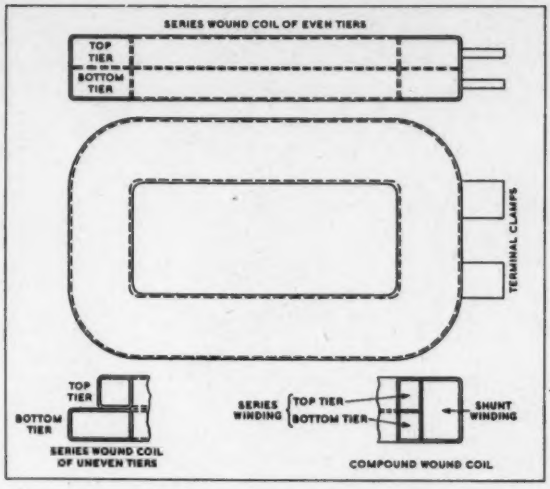



Fig. 2. Diagram showing the construction of field coils in two tiers.

### Designing to Size

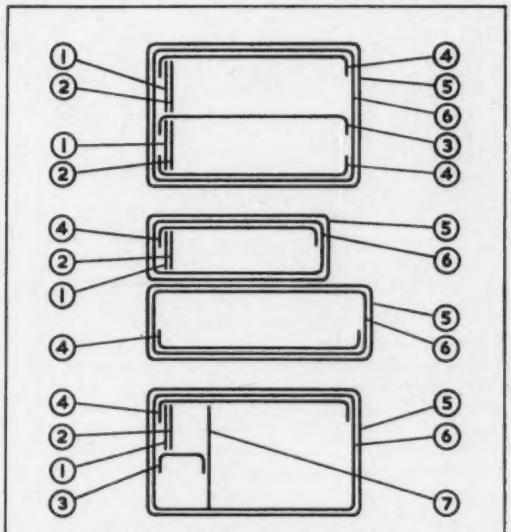
Efficient motor design depends on making the best use of the space available, and it is important to design windings to predetermined dimensions both in depth and width. Only by calculating winding dimensions to an accuracy comparable with a machined component is it possible to arrive at an accurate dimension for the magnet frame or yoke in which the coils are mounted. In order to achieve such accuracy the coils must be moulded by a pressing operation which compresses all the insulating materials capable of compression. This not only results in a coil of minimum possible dimensions, but helps to exclude air for better heat dissipation, and it also results in a stronger and more robust construction. In order that the pressing operation be fully effective, the coils are first dipped in a phenolic hard setting varnish which cures under the action of heat and pressure. Although this process was first developed by the author as long ago as 1937, in modern parlance it could be said that the coil windings are finally embedded in reinforced plastics.

Accurate dimensioning of the coils has a further advantage in that it facilitates the interconnection of cable leads from coil to coil in the magnet frame, because the position of the terminal clamps is almost symmetrical and therefore each lead can be cut to the same length.

Compound coils containing both series and shunt windings are sometimes required, particularly in main generators and auxiliary machines on main-line and shunter-type diesel-electric locomotives. Design and construction of the series portion should follow the same procedure as with a straight series motor coil using strip conductors. Four layers of mica combination are placed along the full depth of the wound series portion. The shunt portion is then wound on top, using round copper wire. In order to provide a smooth and level surface prior to applying the outer insulation, presspahn or other suitable insulation is laid along the armature side. This is cut away where the connector strips lie in position.

### Compression Calculations for Shunt Coils

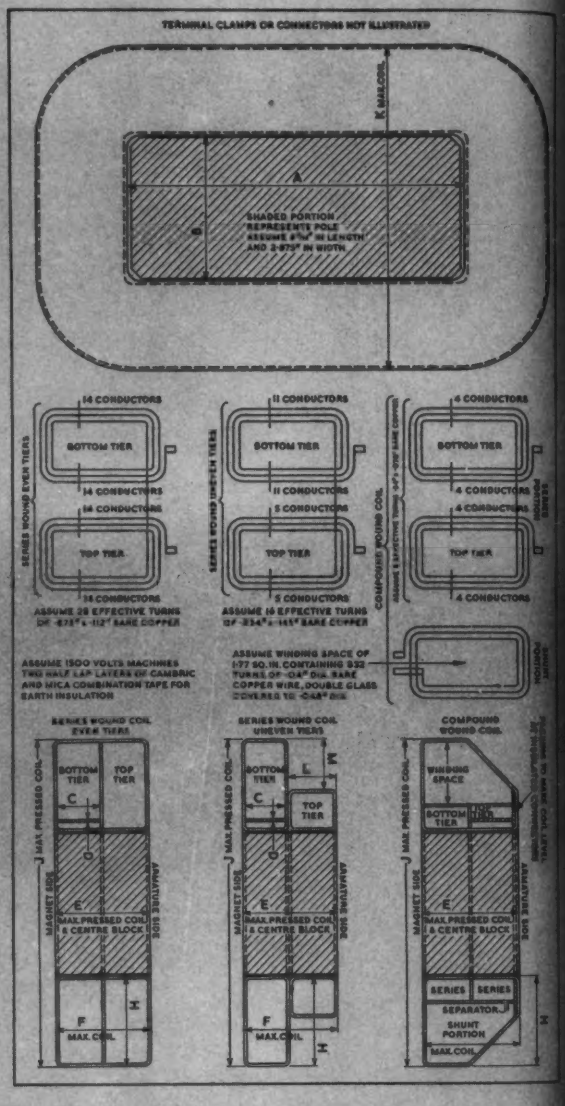
For many years, shunt windings have been manufactured with asbestos-covered round copper wire having a radial thickness of insulation of 0·007 in. This insulation compresses when applying the necessary winding tension, and the space factor can be determined from the following formula:




1. BARE COPPER CONDUCTOR
2. MICA COMBINATION OR ASBESTOS PAPER
3. CAMBRIC AND MICA SHEET
4. CAMBRIC AND MICA SHEET
5. UNIMPREGNATED ASBESTOS TAPE
6. CAMBRIC AND MICA COMBINATION TAPE
7. CAMBRIC AND MICA SHEET

Fig. 3. Insulation of (top) even tiers; (middle) uneven tiers; and (bottom) a compound coil.

**Fig. 4. Method of Obtaining Predetermined Dimensions on Field Coils with Class B Insulation (all dimensions in inches).**




Copper—no compression.
Presspahn Packing—assume no compression.
Asbestos Tape—0·01 thick, after 15 per cent compression = 0·0085.

Mica Combination Interleaf—
0·004 red rope paper.
0·0015 mica.
0·001 jap tissue paper.
0·0015 varnish.
0·001 allowance for building.

0·009 (after 15 per cent compression = 0·0075).

Mica Combination Sheet for Caps and Separators—
0·003 cambric (cotton).
0·0045 mica.
0·001 jap tissue paper.
0·0015 varnish.
0·001 allowance for building.

0·011 (after 15 per cent compression = 0·00935).

Mica Combination Sheet for Earth Insulation—
0·003 cambric (cotton).
0·0045 mica.
0·001 jap tissue paper.
0·0015 varnish.
0·001 allowance for building.

0·011 (after 15 per cent compression = 0·00935).

**A** centre block length = length of pole + 0·20.
**B** centre block width = width of pole + 0·070.
**C** conductor depth.
**D** conductor thickness.
**E** (C × 2) + compressed insulation thickness + packing on compound wound coils.
**F** E + 0·016 (final coating of heat-resisting enamel).
**G** number of conductors.
**H** (G × D) + [(G − 1) × 0·0075] + insulation thickness of width series portion + separator + shunt winding width + insulation thickness (on compound coils).
**J** B + (H × 2).
**K** J + 0·016 (final coating of heat-resisting enamel).
**L** E divided by 2 (on series wound coil of uneven tiers).
**M** G in bottom tier − G in top tier × (D + thickness of compressed interleaf insulation).

*Series Wound Coil Even Tiers*
E = 0·875 × 2 + 0·14985 = 1·89985 (say 1·90).
F = 1·90 + 0·016 = 1·916.
J = 2·945 + 3·552 = 6·497 (say 6·50).
K = 6·50 + 0·016 = 6·516.

*Series Wound Coil Uneven Tiers*
E = 0·834 × 2 + 0·2323 = 1·9003 (say 1·9).
F = 1·90 + 0·016 = 1·916.
J = 2·945 + 3·561 = 6·506 (say 6·50).
K = 6·50 + 0·016 = 6·516.
L = 0·95.
M = 0·915.

*Compound Wound Coil*
E = 0·840 × 2 + 0·1405 + 0·08 (packing) = 1·9005 (say 1·90).
F = 1·90 + 0·016 = 1·916.
J = 2·945 + 3·552 = 6·497 (say 6·50).
K = 6·50 + 0·016 = 6·516.

Note: On series wound coils a curve could be drawn or a table made giving relative total insulation thicknesses varying according to voltage of machine, number of turns in winding and type of machine, i.e. large or small traction motors.
(All calculations based on insulation thicknesses after 15 per cent compression.)

*Table 2. Mica combination*

| Application of insulation (see Table I) | Support | Mica* | Support | Varnish | Total thickness | Thickness after 15% compression |
|---|---|---|---|---|---|---|
| A | Red rope paper 0·004 in. | Single layer | Jap tissue 0·001 in. | Shellac | 0·009 in. | 0·0075 in. |
| B | Jap tissue 0·001 in. | Single layer | Jap tissue 0·001 in. | Shellac | 0·006 in. | 0·005 in. |
| C | Cambric (cotton cloth) 0·003 in. | Three layers | Jap tissue 0·001 in. | Shellac | 0·011 in. | 0·00935 in. |
| D | Cambric 0·003 in. | Three layers | Jap tissue 0·001 in. | Clear extra flexible | 0·011 in. | 0·00935 in. |
| E | Silk 0·0015 in. | Three layers | Silk 0·0015 in. | Clear extra flexible | 0·009 in. | 0·0075 in. |

** All mica used should be first quality clear ruby splittings in book form.*

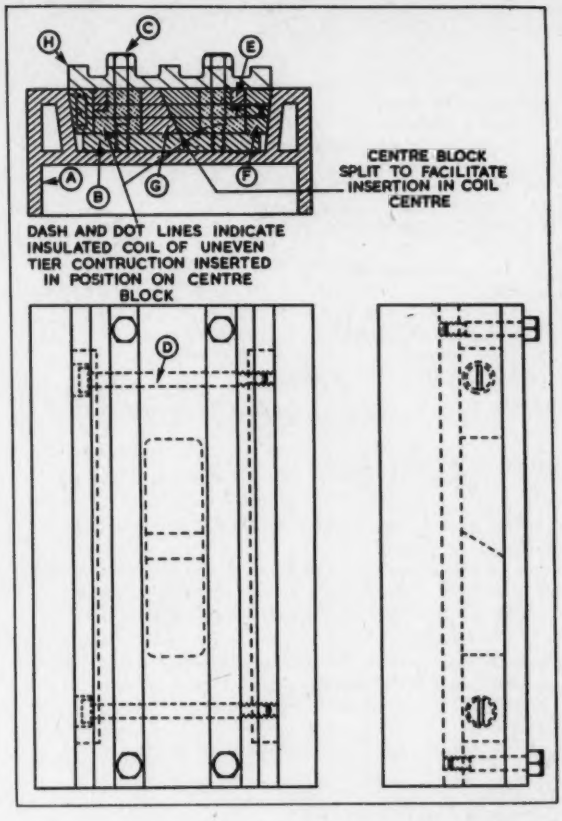



Fig. 5 (right). Pressing gear for field coils.

$$K = \frac{1{\cdot}155}{d^2}$$

where k is the space factor in turns per sq. in; and

d is the overall wire diameter including insulation.

For example, a 0·04-in.-dia. copper wire having a 0·014-in. diametral covering will give a space factor of

$$\frac{1{\cdot}155}{(0{\cdot}04 + 0{\cdot}014)^2} = 396 \text{ turns per sq. in.}$$

The successful introduction of glass-fibre-covered conductors has tended to the replacement of asbestos by glass as a conductor insulation, but although a radial covering of 0·004 in. can be obtained with glass fibres it is not compressible to the same extent as asbestos, and therefore a revised formula is necessary for calculating the space factor:

$$k = \frac{1{\cdot}08}{d^2}.$$

Taking the previous example, but with glass-covered wire, the space factor is now 470 turns per sq. in. This improvement in space factor not only results in a smaller and more even winding but enables the overall size of the machine to be reduced, or, alternatively, enables greater output due to better heat dissipation.

### How a Coil is Moulded

The coil, which is insulated between turns and tiers and fully to earth, should be given a final covering of unimpregnated woven asbestos tape having a cotton binding (nominal thickness 0·01 in.), the cotton content being in accordance with BS 1720: 1951. This tape is applied with a butt joint, but this automatically develops into a half-lap at the corners of a main field coil or at both ends of a semi-circular-ended interpole coil. The coil should now be dried out thoroughly, to remove entrapped solvents and moisture, at a temperature of 110 deg. C. for 4-6 hr. While still hot, the coil should now be dipped in hard-setting phenolic varnish for as long as necessary to ensure thorough penetration. Then, after air drying for 8-10 hr, the coil is ready for moulding.

Fig. 5 shows a typical pressing gear for field coils, and it can be seen that the wedge-shaped blocks on both sides provide side pressure when the equipment is put in a vertical press. In this way the coils are moulded in two directions by one operation. It is important that the amount of insulation calculated for a particular coil is not too great to prevent the press closing completely, otherwise the coil will be oversize. After pressing in hot moulds, the coils are baked for 3 hr. at 160 deg. C., still in their moulds and under pressure from the clamps. Glazed transparent parchment paper is used as a release agent on the centre blocks, and petroleum jelly on the top, bottom and side blocks.

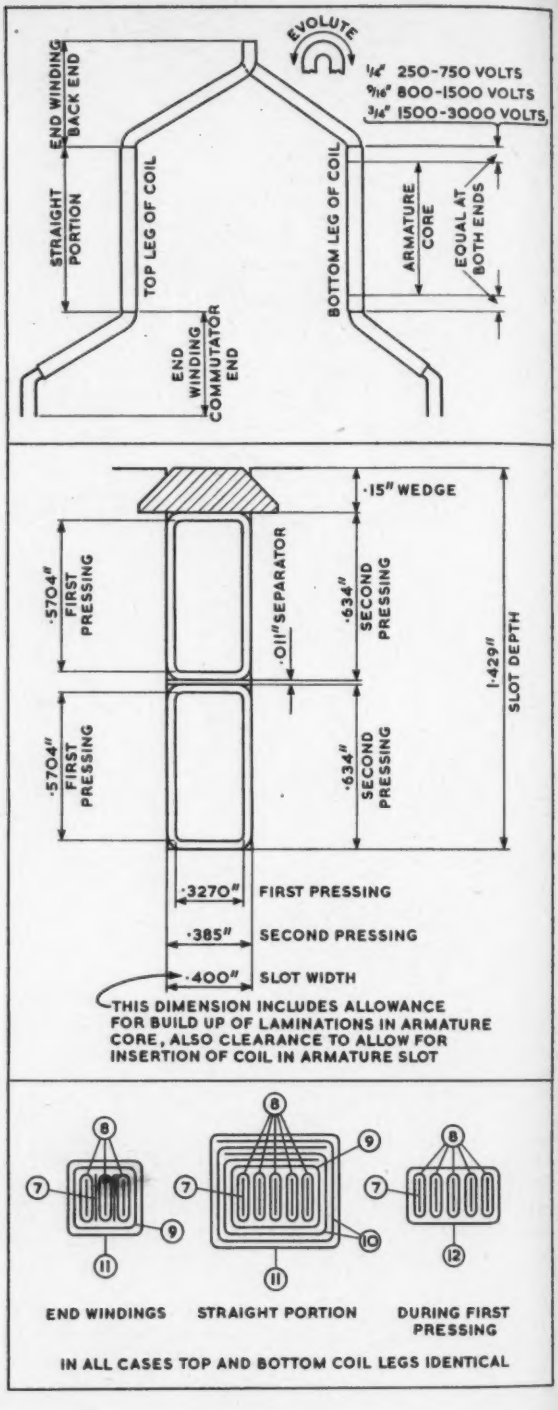
### Calculations for Field Coils

The basis for the design of a completely moulded coil is 15 per cent compression, i.e. the insulation is compressed to 85 per cent of its original nominal thickness. This is given in the form of examples in the last column in Table 2. A full set of calculations for typical coils is given in Fig. 4.

### Armatures

The majority of traction motors and other heavy-duty machines are made with single turn armature coils wound from copper strip which is first cut to length and bent (on edge) into the shape of a hairpin. The number of conductors comprising the coil or slotfull are then formed to coincide with the shape of the armature on which the coils are to be mounted. Each conductor is then insulated with mica combination tape as shown in Fig. 6. The taping should be

Fig. 6. Method for Obtaining Predetermined Dimensions on Armatures with Class B insulation (all dimensions in inches).


EVOLUTE
END WINDING BACK END
1/4" 250-750 VOLTS
9/16" 800-1500 VOLTS
3/4" 1500-3000 VOLTS
STRAIGHT PORTION
TOP LEG OF COIL
BOTTOM LEG OF COIL
ARMATURE CORE
EQUAL AT BOTH ENDS
END WINDING COMMUTATOR END
·15" WEDGE
·5704" FIRST PRESSING
·011" SEPARATOR
·634" SECOND PRESSING
1·429" SLOT DEPTH
·3270" FIRST PRESSING
·385" SECOND PRESSING
·400" SLOT WIDTH
THIS DIMENSION INCLUDES ALLOWANCE FOR BUILD UP OF LAMINATIONS IN ARMATURE CORE, ALSO CLEARANCE TO ALLOW FOR INSERTION OF COIL IN ARMATURE SLOT
END WINDINGS
STRAIGHT PORTION
DURING FIRST PRESSING
IN ALL CASES TOP AND BOTTOM COIL LEGS IDENTICAL

*Assume* 800-1,500 *V., five coils per slot, with a conductor of* 0·550 × 0·045 *bare.*

**7.** bare conductor.
**8.** mica combination tape along conductors.
**9.** mica combination tape (coil overall).
**10.** wrappings along straight portion.
**11.** unimpregnated woven asbestos tape (final covering).
**12.** superfine tape (temporary) removed after first pressing.

Sheets for Manufacture of **8**—
0·001 silk.
0·0015 mica.
0·001 jap tissue paper.
0·0015 varnish.
0·001 allowance for building.

0·006 (after 15 per cent compression = 0·0051).

Sheets for Manufacture of **9**—
0·001 silk.
0·0015 mica.
0·001 silk.
0·0015 varnish.
0·001 allowance for building.

0·006 (after 15 per cent compression = 0·0051).

Separate Wrappings in Conjunction with Each Other, **10**—
0·0055 mica and bonding varnish.
0·001 glazed transparent parchment paper.

0·0065 (after 15 per cent compression = 0·00525).

**11.** 0·010 Unimpregnated Woven Asbestos Tape—after 15 per cent compression = 0·0085.
**12.** 0·0065 Superfine Tape—after 15 per cent compression = 0·00525.

First Pressing Depth—
1 × 0·550 = 0·550 (bare copper)
4 × 0·0051 = 0·0204 **8**
2 × 0·00525 = 0·0105 **12**

0·5809 (before removal of **12**)
= 0·5809 − 0·0105 (after removal of **12**)
= 0·5704

Second Pressing Depth—
4 × 0·0051 = 0·0204 **9**
5 × 0·00525 = 0·02625 **10**
2 × 0·0085 = 0·0170 **11**

0·06365 (compressed insulation)

Coil after first pressing = 0·5704
Compressed insulation = 0·06365

0·63405 (say 0·634)

First Pressing Width—
5 × 0·045 = 0·2250 (bare copper)
20 × 0·0051 = 0·102 **8**
2 × 0·00525 = 0·0105 **12**

0·3375 (before removal of **12**)
= 0·3375 − 0·0105 (after removal of **12**)
= 0·3270

Second Pressing Width—
4 × 0·0051 = 0·0204 **9**
4 × 0·00525 = 0·0210 **10**
2 × 0·0085 = 0·0170 **11**

0·0584 (compressed insulation)

Coil after first pressing = 0·3270
Compressed insulation = 0·0584

0·3854 (say 0·385)

Slot Depth—
0·150 armature slot wedge.
0·634 coil depth, top leg.
0·011 separator.
0·634 coil depth, bottom leg.

1·429

Slot Width—
0·385 coil width
0·010 build up of armature laminations.
0·005 clearance.

0·400

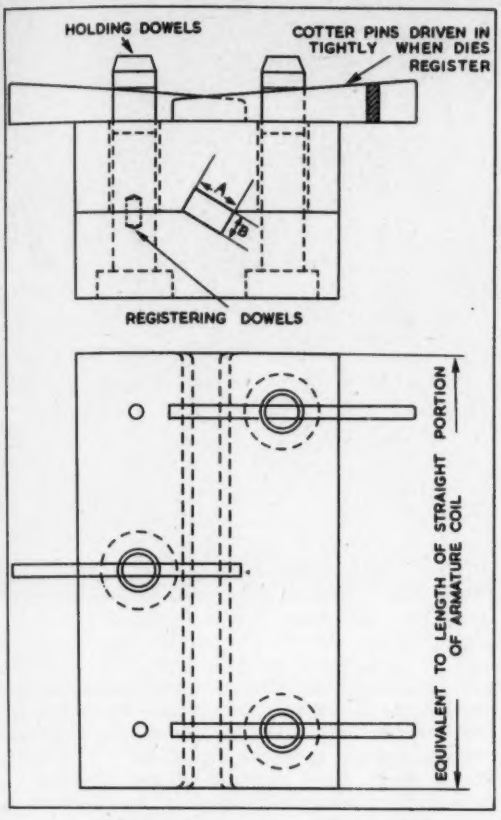

HOLDING DOWELS
COTTER PINS DRIVEN IN TIGHTLY WHEN DIES REGISTER
REGISTERING DOWELS
EQUIVALENT TO LENGTH OF STRAIGHT PORTION OF ARMATURE COIL

Fig. 7. Pressing gear for armature coils.

applied half-lap from end to end of the coil if space is available. Where space is restricted, the portion of the coil beyond the straight portion (called the end winding) need have only alternate conductors insulated. In this case it is advisable to insulate the outer coils; for instance with five coils per slot, 2 and 4 are left bare. The sequence of operations for completing the insulation of the coil is as follows:

(1) U-shaped separators of epoxy-impregnated glass cloth are inserted between coils at the evolute.
(2) The assembled coils are taped butt joint with a temporary cotton superfine tape impregnated in paraffin wax to facilitate removal later on.
(3) The first pressing operation consists of moulding the straight portion of the coil in steel blocks which have been preheated to 160 deg. C. (see Fig. 7).
(4) After removal of the temporary cotton wrapping, the main insulation to earth is applied. This consists of one to three wrappings (according to voltage), each wrapping having three layers of mica bonded with shellac varnish. Two wrappings of glazed transparent paper are used in conjunction with the mica sheet to assist the wrapping operation.
(5) The assembled coils are now covered with one layer of butt jointed unimpregnated asbestos tape, the straight portion being brushed with phenolic varnish, and the end windings with a black flexible baking varnish.
(6) After drying at 90 deg. C. for 1 hr., the coil is given a second pressing operation to bring it down to predetermined dimensions.

A typical design of armature coil is illustrated in Fig. 6. In order to ensure a satisfactory fit in the slot the armature core laminations should be manufactured to dimensions −0·000 + 0·004 in. in depth and −0·000 + 0·003 in. width. Coils should be used within a reasonably short period after manufacture, and while the end windings retain some flexibility to enable them to be mounted into the armature coil slots.

The successful design of electrical insulation on traction machines is dependent on the issue of precise manufacturing specifications covering all processes. This is particularly important in respect of the varnishes and baking processes.

(To be continued in the March issue.)

# THE HOT WATER ROCKET

THE main characteristics of the hot water rocket are its great economy, its simplicity and safety. A disadvantage is its considerable weight, which makes it hardly suitable for use in flight, but there are still enough applications to warrant its use on the ground.

Greatly simplified, the hot water rocket can be imagined as a steel cylinder, on the valve head of which a tap and a Laval nozzle are mounted. The container is filled about three-quarters full with water, which is heated in a suitable manner. After a certain pressure (40 or 50 atmospheres) is reached, the tap is opened and the hot water flows out. Part of it evaporates in the process, and the released heat energy accelerates the ejected jet, producing the thrust.

In the container itself, a fall of pressure occurs during the discharge, since the volume vacated by the water is filled up by steam. This steam, however, can only be taken from the water that is still in the container; this causes a further decrease of pressure. The fall of pressure occurs linearly, decreasing by about 25 per cent; the extent of the fall is dependent on the relative nozzle measurements.

The first problem in the operation of the hot water rocket is that of heating the water. There are two possibilities. First, the rocket can be filled with cold water and heated by internal heating installations, e.g. by an oil or gas burner. The second possibility lies in heating the water in a separate high-pressure boiler plant, from which it is filled into the boiler of the hot water rocket at the desired initial pressure.

The greatest asset of the hot water rocket lies in its use as a starting aid, and it could be of great use for the modern jet-propelled commercial aircraft, which under present conditions require a considerable extension of the runways.

The design of the hot water rocket starting aid was originated at the Count Zeppelin Research Institute, the rocket being heated by a built-in Schmidt impact burner. For take-off, this rocket was mounted on a trolley connected to the aircraft, the trolley being eventually detached from the plane and decelerated. Various hot water rocket starting trolleys of this kind were developed in 1941 by Herr Schwarzler in the Heinkel works.

Also projected at the Count Zeppelin Research Institute was a design for a sled on tracks. Subsequent developments included the starting trolley for the Me 262 (Messerschmitt jet plane) at the end of the Second World War. In this, the aircraft, starting rocket and trolley ran on tracks on the runway. Take-off velocity was set at 212 m.p.h., a hot water rocket producing the required thrust for 14·5 sec.

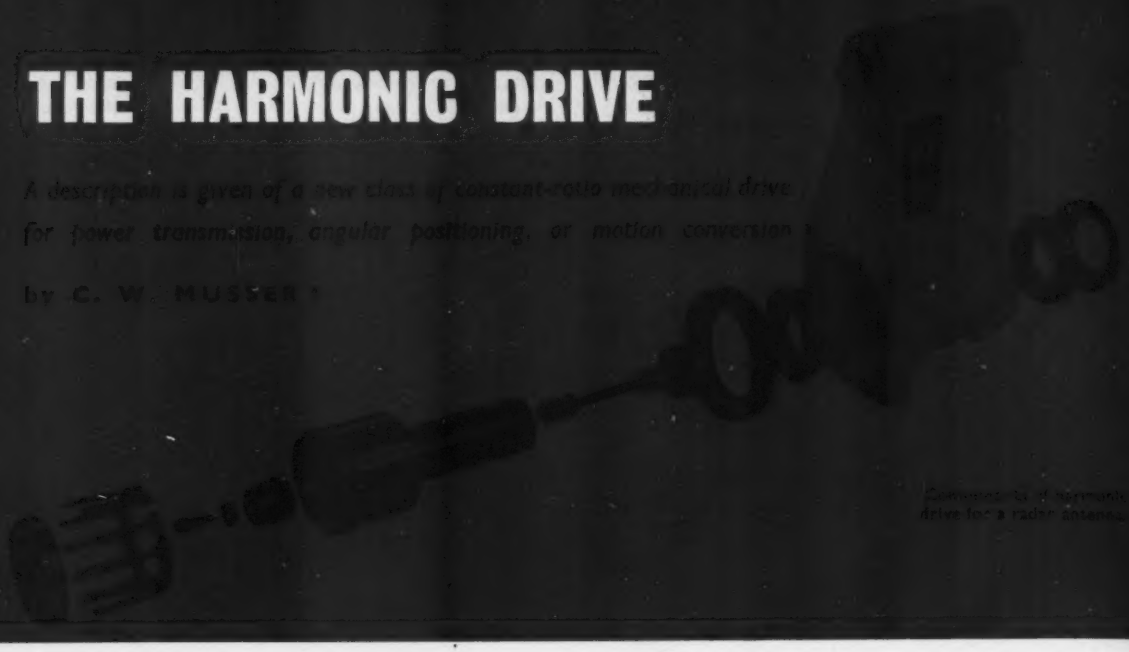
Future possibilities may be in the application of the hot water rocket for civilian projects, such as intercontinental mail and freight rockets.

Abstracted from an article by Otto Muhlhäuser, in *Rakentechnik und Raumfahrtforschung*, 2, No. 7, p. 45-49, 1958.

# THE HARMONIC DRIVE

A description is given of a new class of constant-ratio mechanical drive for power transmission, angular positioning, or motion conversion

by C. W. MUSSER *



Comparison of harmonic drive for a radar antenna

DESIGN of most mechanical drive systems in use today is based on the set of "laws" collectively defined as "rigid-body mechanics". Rotating elements are assumed to remain rigid and to rotate circularly about fixed axes.

Departing radically from these traditional concepts, a new family of drive systems has recently been developed. They use controlled elastic deflection of one or more parts for transmission, conversion or change of mechanical motion. Called harmonic drive, these systems achieve high mechanical leverage by generating a travelling deflection wave in a flexing spline element.

A simplified form of the principle of controlled elastic deflection is illustrated in Fig. 1, where semi-elliptical springs are the flexible component.

Conversion of the simple spring-deflection system into a continuous rotational machine is shown in Fig. 2. Here, two toothed rings are in partial mesh. The rigid outer ring has internal spline teeth; the thin, flexible inner ring, external spline teeth.

The third element in this rotary system is the "wave generator", which rotates within the flexible spline and deflects it slightly from its natural circular form into an elliptoidal shape. The wave generator develops the radial force and displacement illustrated in the system of Fig. 1.

With the two-lobe wave generator shown in Fig. 2, the flexible spline meshes with the circular spline at two diametrically opposite regions on the major axis of the elliptoid. Teeth of the two splines clear at the minor axis.

Teeth on the flexible and circular splines are cut to the same circular pitch. But the number of teeth on the smaller flexible spline is slightly less than on the circular spline. To allow engagement at two diametrically opposite regions, the tooth arrangement must be symmetrical. For a two-lobe system having two regions of tooth engagement, the difference in number of teeth on the two splines must be an integral multiple of the number of lobes; that is, 2, 4, 6, etc. The pitch circle of the flexible spline is made smaller than that of the circular spline in proportion to the difference in the numbers of teeth.

The regions of spline engagement in Fig. 2 correspond to the pivoted ends *A* and *B* of the semi-elliptical springs in Fig. 1. The minor-axis regions of spline disengagement correspond to the positions of the swinging shackles at points *C* and *D*. As the wave generator is rotated clockwise toward the dotted position shown in Fig. 2, the flexible spline is deflected progressively outward, causing continuous and greatly reduced tangential motion of the flexible spline. Motion of the flexible spline is in a counterclockwise direction for clockwise motion of the wave generator. For a full revolution of the wave generator, the flexible spline will counter-rotate through an angle proportional to the difference in the number of teeth on the two splines.

The distinctive characteristics of this drive system can be seen from the simple model in Fig. 2. Flexible and circular splines are fully engaged at the major axis, but move angularly relative to one another at all other points, with maximum relative motion occurring at the minor axis. If the wave generator is rotated clockwise at a constant angular velocity, the flexible spline will counter-rotate at a constant, but greatly reduced, average angular velocity. This characteristic is the basis for high-reduction rotary systems.

Reversibility of this drive system is also apparent. If the two swinging shackles at points *C* and *D* (Fig. 1) are displaced in the tangential directions shown, the springs will be deflected radially as indicated. Similarly, in the harmonic drive (Fig. 2) a small counterclockwise rotation of the flexible spline will induce a magnified clockwise rotation of the wave generator. This characteristic is the basis for high-ratio speed-increaser systems.

### Spline Motion Relationships

A better picture of the operation of the drive elements is provided by Fig. 3, which shows a working demonstration model. Here, the wave generator is elliptoidal in shape and is surrounded by a ball bearing. The flexible spline has 130 teeth and the circular spline 132 teeth. The two-tooth difference equals the number of lobes of the wave generator.

As the wave generator is turned, the flexible spline is progressively deflected to follow the rotating elliptoidal shape. Flexible and circular splines are held in engagement at the major axis of the wave generator, and are fully disengaged and clearing at the minor axis. Magnified views

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show successive conditions of spline-tooth engagement and disengagement. The views at the left show tooth action at any one region of the circular spline as the wave generator is rotated. Starting at the fully engaged position, the tooth on the flexible spline gradually disengages, advances and re-engages, as the wave generator is turned a half revolution. For a full rotation of the wave generator, the flexible spline counter-rotates through an angle equivalent to two of its 130 teeth, giving a 65 : 1 reduction ratio.

In these drive systems any one of the three basic elements (wave generator, flexible spline or circular spline) can be held fixed, and the other two used interchangeably as input and output. Design relationships for the basic rotary single-stage combinations are given in Fig. 4.

With the circular spline fixed, high input/output ratios with reversal in direction of rotation are obtained. The circular spline is stationary, input rotation being introduced through the wave generator, and output rotation taken from the flexible spline. If the circular spline has 200 teeth and the flexible spline 198, the flexible spline rotates counter-clockwise two of its teeth for each clockwise revolution of the wave generator, or

$$R = \frac{N_F}{N_F - N_C} = -\frac{99}{1}$$

Where the flexible spline is fixed, high input/output ratio with rotations in same direction results. The wave generator introduces input rotation, the flexible spline being held stationary, and output rotation taken from the circular spline. If the circular spline has 200 teeth and the flexible spline 198, one clockwise revolution of the wave generator advances the circular spline two of its teeth, or

$$R = \frac{N_C}{N_C - N_F} = \frac{100}{1}$$

With the wave generator fixed, drive ratios near unity with input and output rotation in same direction are obtained. The wave generator is stationary, the flexible spline introducing input, and output is taken from the circular spline. If the circular spline has 200 teeth and the flexible spline 198, this arrangement produces near-unity reduction, or

$$R = \frac{N_C}{N_F} = \frac{100}{99}$$

### Design Details

Current design practice for the spline elements of these systems is based on the use of the standard 30-deg. involute SAE spline tooth form. This tooth form is usually modified by changing the height slightly to allow sufficient clearance for engagement and disengagement.

However, this tooth shape is in no way mandatory. In fact, from a theoretical viewpoint, a straightsided tooth would appear to be a better choice. But this shape would entail a special cutter for each diameter. Other pressure angles can also be used with the involute form as long as the tooth height is altered to provide the necessary clearance.

A number of materials have been used successfully in the design of the drive elements. Preferred choice has been SAE 4340 steel, primarily because of the specifications on metallurgical cleanliness that have been established for this material. However, this cleanliness requirement is only of importance for those parts which are thin and have alternating stresses imposed on them. In this respect, the problems are not any more critical than for other machine elements.

Although the flexing elements are subjected to cyclic-stress conditions, fatigue has not been a particular problem. For example, the calculated maximum stress in some experimental 100 : 1 reduction units varies from 9,000 p.s.i. for one design to 18,000 p.s.i. for another. Actual strain-gauge measurements indicate that the stress level at the most highly stressed point is considerably less than the endurance limit of any steel.

### Unique Properties

From the description of the basic rotary drive system, several unique and inherent properties become apparent:

1. Tooth motion relationship between flexible and circular splines makes high-ratio speed reduction or speed increase possible in a single stage.

2. In operation, many spline teeth are in simultaneous engagement to carry torque loads. Teeth adjacent to load-bearing teeth are in near-engagement, and provide a "reserve" capacity to accommodate shock overloads.

3. Spline teeth come into contact with an almost pure radial motion, and have essentially zero sliding velocity, even at high input speeds. Tooth friction losses and wear are thus negligible.

4. Spline teeth in contact are practically stationary. Dynamic loading, under normal operating conditions, is negligible, and splines are thus capable of transmitting

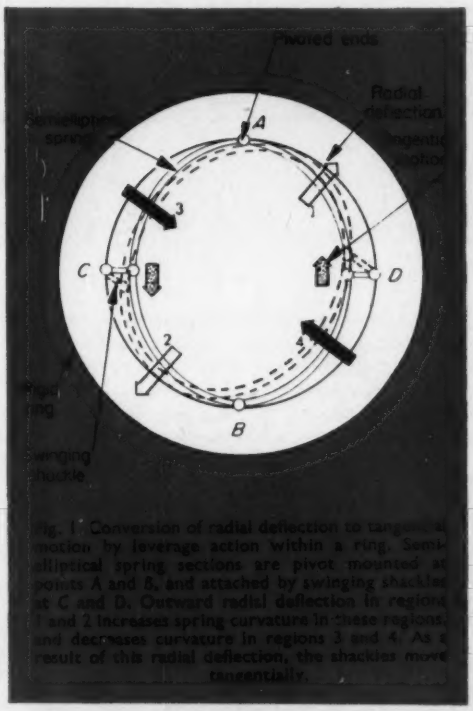



Fig. 1. Conversion of radial deflection to tangential motion by leverage action within a ring. Semi-elliptical spring sections are pivot mounted at points A and B, and attached by swinging shackles at C and D. Outward radial deflection in regions 1 and 2 increases spring curvature in these regions and decreases curvature in regions 3 and 4. As a result of this radial deflection, the shackles move tangentially.

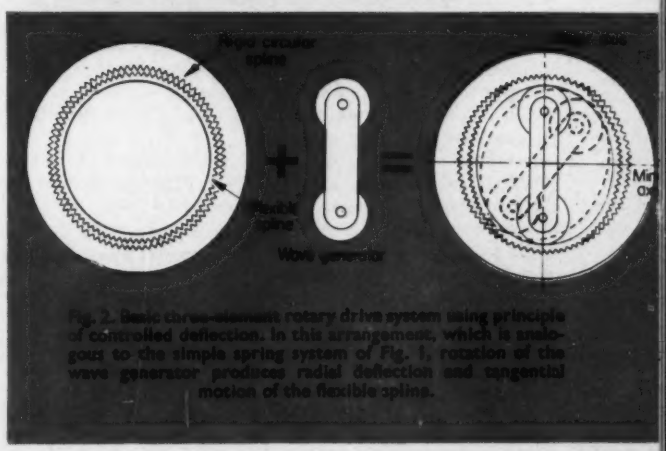



Fig. 2. Basic three-element rotary drive system using principle of controlled deflection. In this arrangement, which is analogous to the simple spring system of Fig. 1, rotation of the wave generator produces radial deflection and tangential motion of the flexible spline.

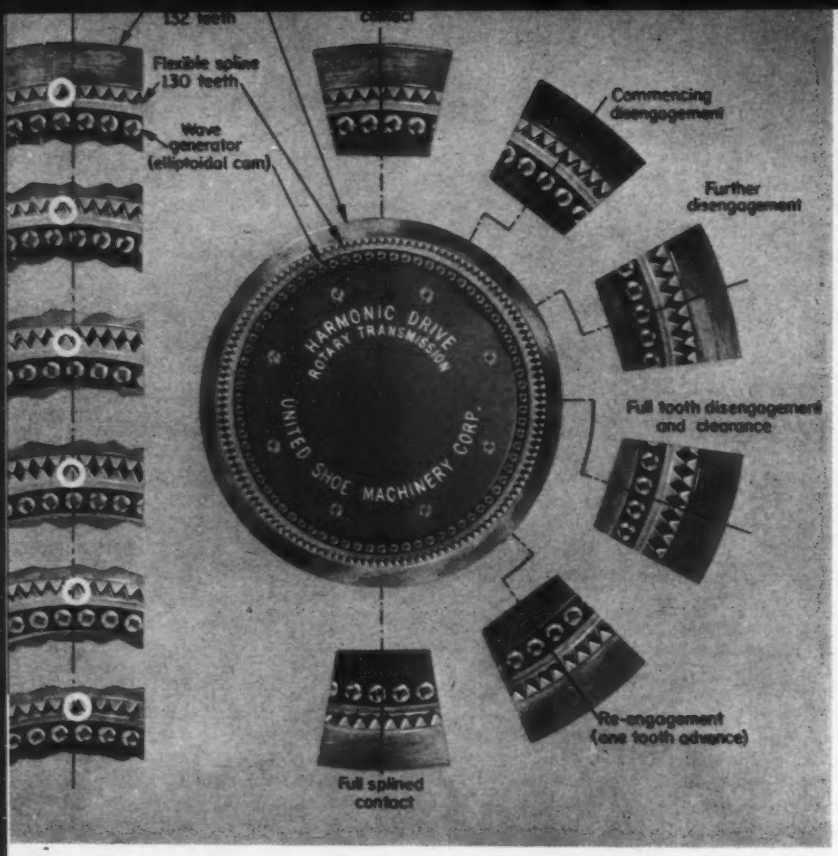



Fig. 3. Spline motion relationships in rotary single-stage drive. Magnified views at the left show the progressive action of the single tooth during the clockwise half-revolution of wave generator. The radial views show the successive tooth relationships between circular and flexible splines.

torques nearly in proportion to their static strength.

5. Regions of tooth engagement and application of load torque are usually diametrically opposed, and result in a force couple that is symmetrical and balanced.

6. Diametrically opposed spline mesh, and the large number of teeth in simultaneous engagement, result in a statistical averaging of errors in individual tooth shape and placement.

7. With the flexible spline formed as an integral section of a flexible cylindrical wall, positive transmission of mechanical motion through the wall can be achieved.

### Wave Generator Configurations

The role of the wave generator is to produce controlled deflection of the flexible spline, and to make possible the continuous rotation of the resulting elliptoidal shape. Up to now, the systems discussed have used internal wave generators which deflect the flexible spline outwards into engagement with the circular spline. Wave generators can also be external to deflect the flexible spline inwards into engagement with the circular spline. In this instance, spline engagement is at diametrically opposite regions on the minor axis of the elliptoid. Fig. 5 shows a few of the many possible forms of wave generator.

ELLIPTOIDAL CAM—The most common form of wave generator is the elliptoidal-cam type (Fig. 5a). It may be either internal or external, and may have plain or anti-friction bearing contact with the flexible spine.

SPACED ROLLER—An inexpensive form of wave generator is the spaced roller type. It can easily form two or more lobes, and may also be internal or external (Fig. 5b). Standard ball bearings can be used as anti-friction devices at the points of contact with the flexible spline. Because the flexible spline is unsupported between wave-generator lobes, drives using the spaced-roller design do not have as high an output load capacity as those using the elliptoidal-cam type.

BALL PLANETARY—Another useful form of wave generator is the ball-planetary type (Fig. 5c). This consists of a circular inner bearing race which acts as a sun wheel and drives two or more radially-loaded balls. Because the balls are loaded radially, the load forces are balanced and symmetrical at the regions of spline engagement. Thus a spacer is not mandatory to keep the balls separated. However, the spacer may be helpful for assembly of the balls, and to prevent displacement under accidental shock loading. A feature of the ball-planetary wave generator is that its reduction ratio can be varied from approximately 2·2 to 8:1, to supplement spline action and increase the overall drive reduction. When a selection of ball-planetary wave generators is available, the reduction ratio of a drive stage can be changed readily to meet a wide range of ratio requirements.

VARIABLE-BALL PLANETARY—A variation of the ball-planetary wave generator utilises several balls of varying size, interposed between the two or three largest balls (Fig. 5d). These additional balls do not vary the reduction ratio of the wave generator, but support the flexible spline, share the bearing load, and thus increase the torque capacity of the drive unit.

### Flexible-spline Design

The wave generator and the circular spline can be joined rigidly or rotationally to external equipment by standard coupling methods. However, the flexible spline requires less conventional techniques of position and motion coupling. For most applications, motion of the flexible spline is transmitted through a type of coupling which integrates the variations in angular velocity previously mentioned and produces a uniform angular motion. Four types of such couplings are shown in Fig. 6.

INTEGRAL COUPLING—From a performance view, the preferred flexible spline couplings are integral members (Fig. 6a). The coupling is in the form of a cup with spline teeth

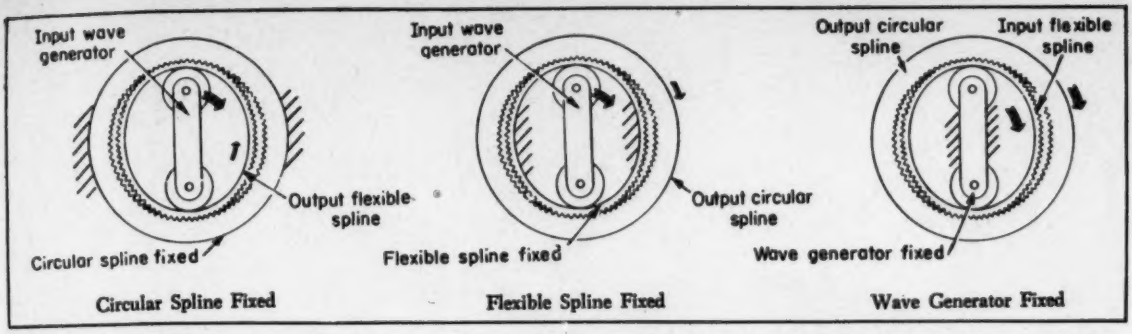



Fig. 4. Design relationships for single-stage rotary drive systems. Arrangements shown are for speed reduction service; $R$ = drive ratio, $N_C$ = number of teeth on circular spline, $N_F$ = number of teeth on flexible spline.

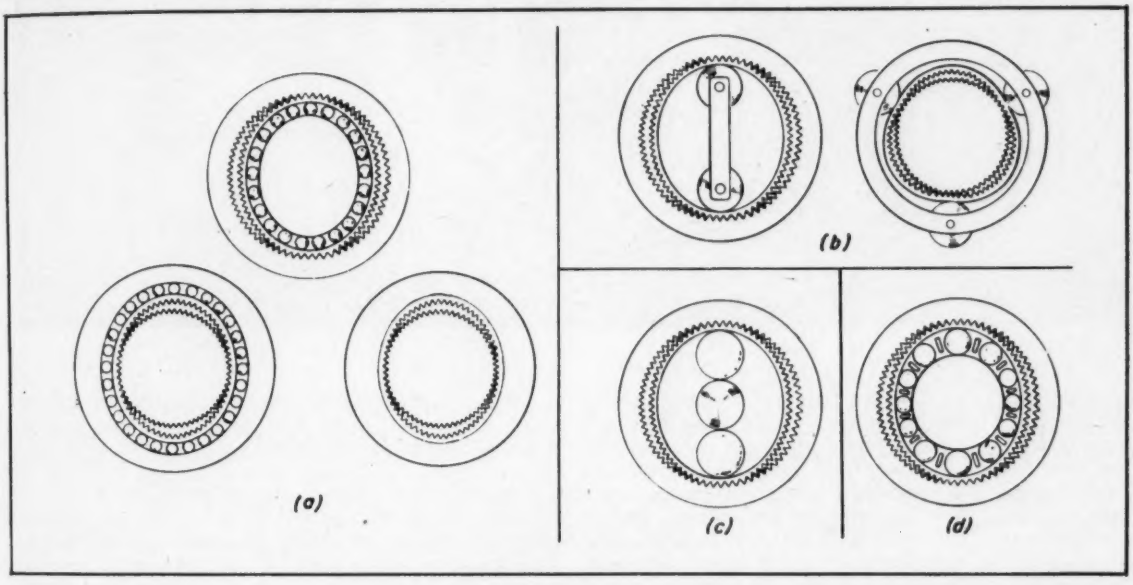



Fig. 5. (*above*) Wave generator configurations: (a) elliptoidal cam; (b) spaced roller; (c) ball planetary; (d) variable-ball planetary.

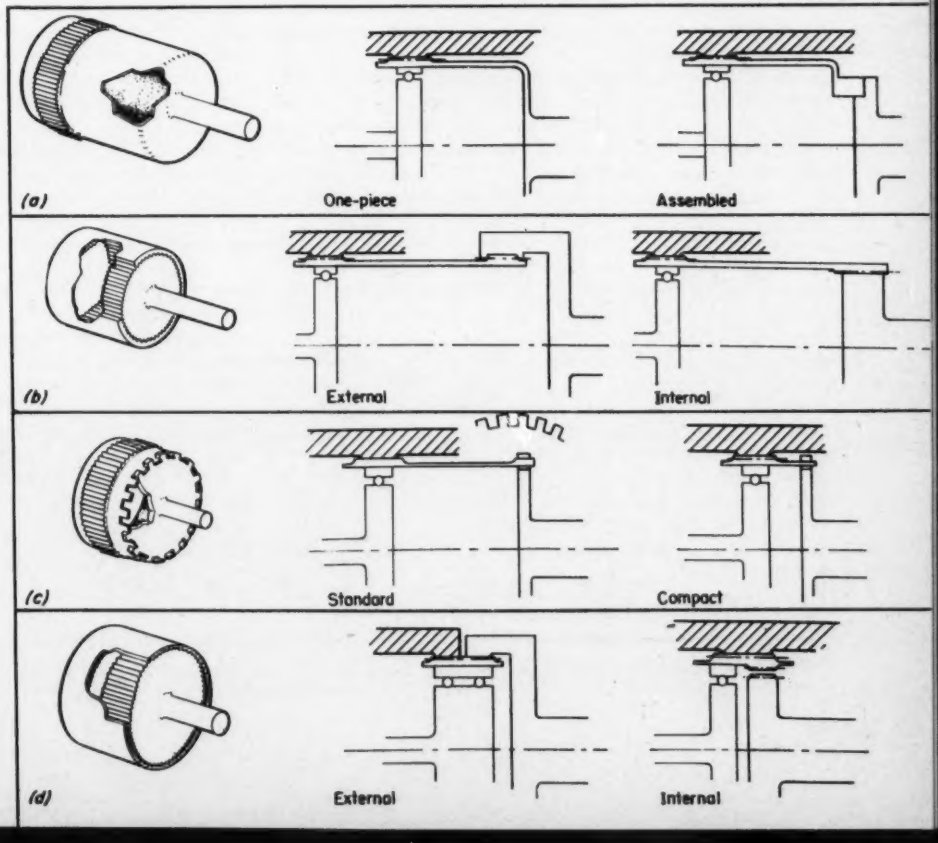



Fig. 6. Types of flexible-spline coupling: (a) integral; (b) static spline; (c) castellated; (d) dynamic spline.

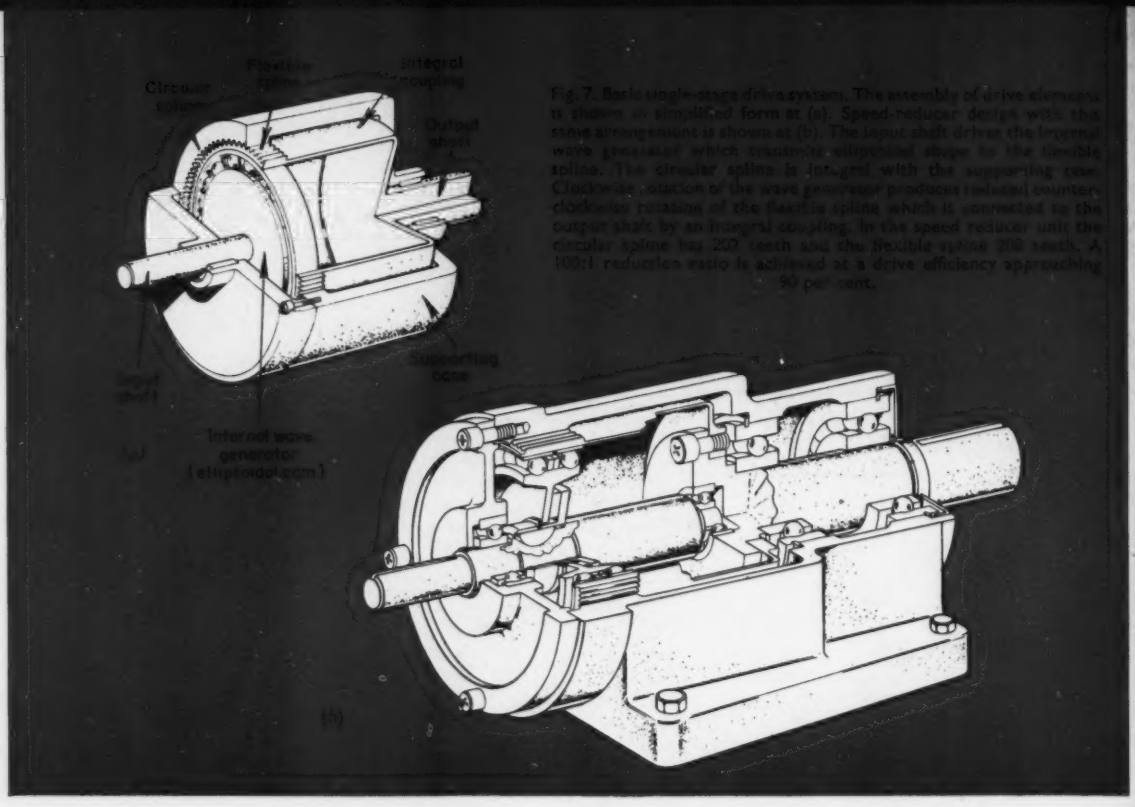



Fig. 7. Basic single-stage drive system. The assembly of drive elements is shown in simplified form at (a). Speed-reducer design with this same arrangement is shown at (b). The input shaft drives the internal wave generator which transmits elliptical shape to the flexible spline. The circular spline is integral with the supporting case. Clockwise rotation of the wave generator produces reduced counter-clockwise rotation of the flexible spline which is connected to the output shaft by an integral coupling. In the speed reducer unit the circular spline has 202 teeth and the flexible spline 200 teeth. A 100:1 reduction ratio is achieved at a drive efficiency approaching 90 per cent.

in the cylindrical wall near the open end. Controlled deflection is imposed in the cup at the open end, while the closed end remains essentially circular. The length of the tubular wall acts as a deflection attenuator, and provides a form of integrating coupling between the spline engagement at the open end and a shaft joined to the cup bottom. Integral couplings have high torsional rigidity, low backlash, long life, high torque capacity and no power loss within the coupling. Drive efficiencies with integral couplings can be over 90 per cent. The assembled coupling can contain a drive motor, overload clutch, or electrical control circuits for effective space utilisation.

STATIC SPLINE—The next most efficient coupling is the static design (Fig. 6b). Here, the flexing spline is at one end of an open tube and a standard circular spline engages the other end. Coupling spline teeth can be cut either externally or internally into the tube wall. The static-spline coupling permits slight axial motion of the tube without allowing angular or radial freedom. The operating efficiency of the static spline is slightly less than that of an integral coupling. Fabrication cost is lower, but the static spline requires lubrication.

CASTELLATED COUPLING—The efficiency, positioning accuracy and torque capacity of the castellated coupling (Fig. 6c) are governed by the number of lugs and the tube length between spline teeth and lugs. Maximum compactness is possible with this type of coupling. The shorter couplings, however, have about one-fourth the load capacity of an integral coupling, since torque is not equally distributed among the lugs. Castellated couplings have lower positioning accuracy and efficiency, but are the least expensive and most compact coupling form for a single-stage drive.

DYNAMIC SPLINE—A unique form of spline coupling is shown in Fig. 6d. The teeth of the flexible spline can be extended along the inner or outer wall of the flexing tube,

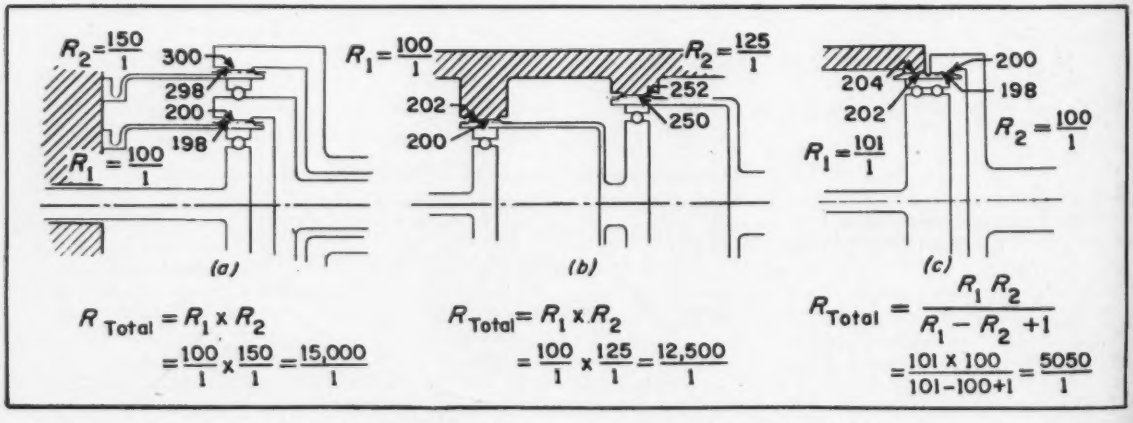



Fig. 8. Multiple-stage drive systems: (a) radial compound; (b) axial compound; (c) dual. Ratio calculations are based on numbers of teeth indicated.

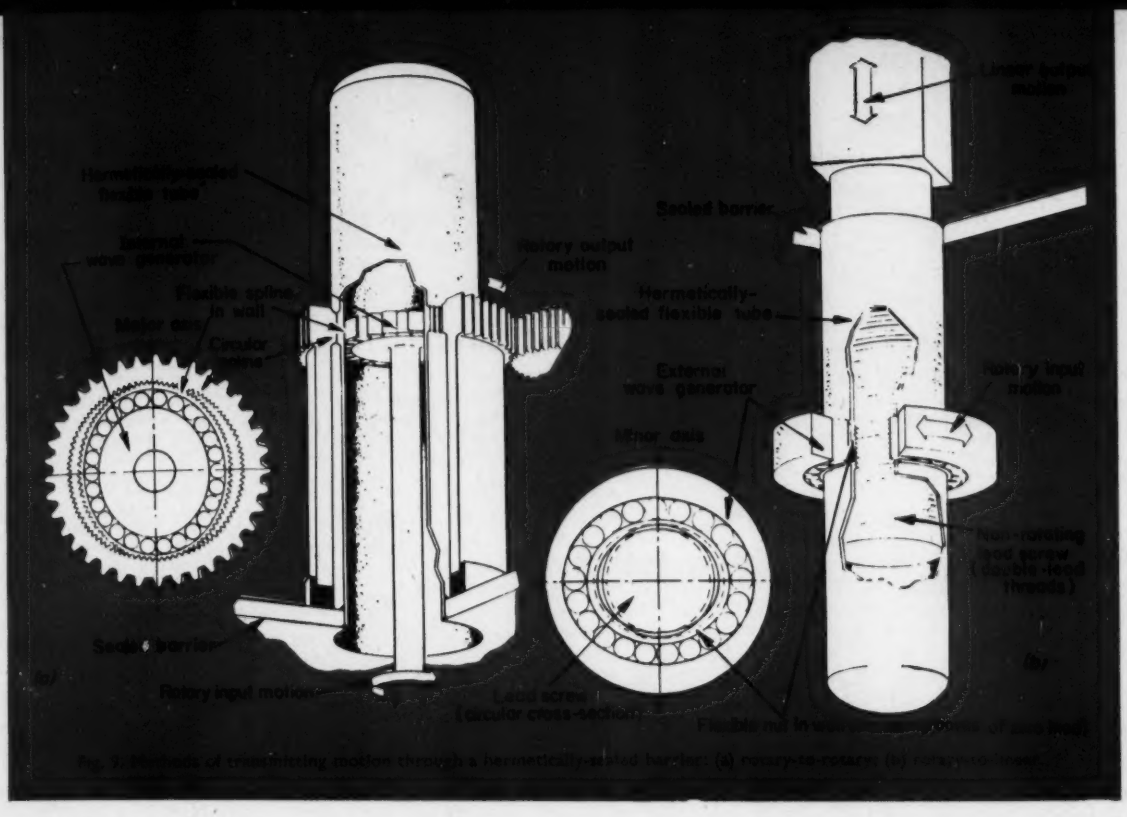



Fig. 9. Methods of transmitting motion through a hermetically-sealed barrier: (a) rotary-to-rotary; (b) rotary-to-linear.

or teeth can be provided on both inner and outer walls. A second circular output spline engages the elliptoidal flexible spline either externally at the major axis, or internally at the minor axis. The circular output spline has the same number of teeth as the engaging spline on the flexing tube. Thus, the two splines move in unison, causing motion of the flexible spline to be transmitted directly to the shaft. The dynamic-spline coupling is compact, and offers high positioning accuracy. Load-carrying capacity, however, is about one-third that of the integral coupling, and drive efficiency with this type of coupling is about 65 per cent.

### Drive Systems

How the principal operating elements previously discussed are combined to form a single-stage drive system is shown in Fig. 7. This basic drive unit has an internal elliptoidal-cam wave generator, a flexible spline with integral coupling to the output shaft, and a circular spline machined in the supporting case. While the drive is shown as a speed reducer, it can be used equally well as a speed increaser by interchanging the functions of input and output shafts.

Single-stage systems can be used in several ways, as shown in Fig. 4. The range of application of this new type of mechanical system is further extended when drive stages are combined to form multiple-stage systems. By combination of internal and external wave generators, flexible splines with multiple sets of teeth, and internal or external circular splines, an almost limitless number of useful mechanical arrangements can be derived. Typical compound and dual systems are shown in Fig. 8.

Compound Drive—Drive stages can be compounded radially or axially. In the radial arrangement (Fig. 8a), the input wave generator (the innermost element) drives the first-stage circular spline with 100:1 speed reduction. The flexible spline for this stage is rotationally fixed to the supporting case.

The first-stage circular spline forms the input wave generator of the second stage. The flexible spline of this stage is also held stationary, and the second-stage circular spline provides the output motion of the two compounded stages. If the second stage provides a 150:1 reduction, the total ratio from first-stage input to second-stage output is 15,000:1.

An axial-compound drive is produced when the circular splines are anchored (Fig. 8b), and the first-stage flexible spline drives the second-stage wave generator. With ratios calculated on the basis of the flexible spline motion, the drive shown produces an overall reduction of 12,500:1. Other forms of compound drive can also be built up, and ratios of 1,000,000:1 can be achieved with only two compounded stages.

Dual Drive—The term "dual" defines systems in which one or more of the principal elements serve two separate sets of engaging splines. In Fig. 8c, for example, a single flexing member carries two sets of spline teeth, and a single elliptoidal wave generator causes these two flexible splines to engage separate circular splines at the major axis.

The high-ratio dual drive shown has one spline engagement between a flexible spline and a stationary circular spline. Another spline engagement occurs between a second flexible spline and an external circular spline which produces the output rotation. As the wave generator is rotated, the two sets of splines produce rotations in opposite directions to develop a differential action. The two sets of splines have separate ratios of 101:1 and 100:1. In combination, they produce an overall dual reduction of 5,050:1.

A form of intermediate-ratio dual drive results if the output circular spline engages the flexing member internally at regions on the minor axis of the elliptoid. The additive action of the two resulting sets of splines produces a dual reduction ratio of about one-half that of a conventional single-stage system.

### Sealed Drive Systems

A unique and useful characteristic of this type of drive system is its ability to transmit mechanical motion through sealed walls (Fig. 9). The wall can be part of a welded steel enclosure which is capable of maintaining complete

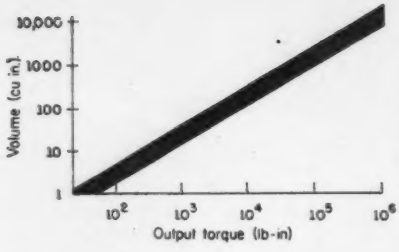



Fig. 10. External volume versus output torque. The plot is representative of systems with 100:1 drive ratio. The band of values indicates the practical design range from 25-50 lb.-in. per cu. in.

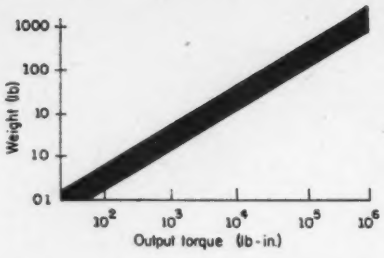



Fig. 11. Weight versus output torque.The band is representative of 100:1 ratio drive systems. The range of practical design can vary from 150-500 lb.-in. per lb.

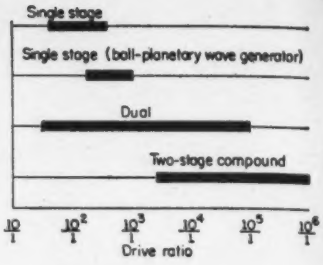



Fig. 12. Ranges of preferred drive ratios for four drive configurations. The plot shows the general ranges possible with steel flexible splines in units of moderate physical size.

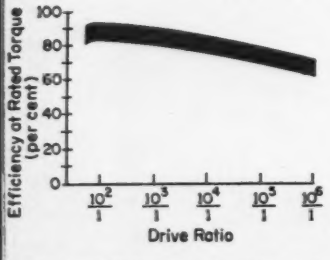



Fig. 13. Efficiency versus drive ratio. The values apply to steel flexible splines with integral couplings, and include losses of both input and output shaft bearings.

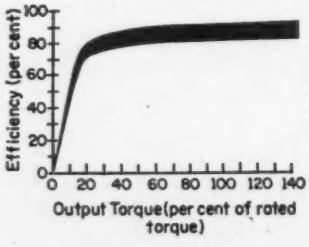



Fig. 14. Efficiency versus output torque. The plot applies to the single-stage drive system with integral coupling to flexible spline.

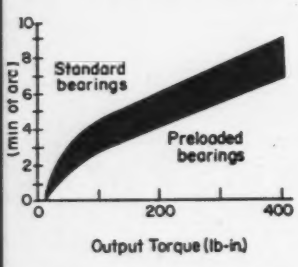



Fig. 15. Wind-up versus output torque. The plotted values are based on a specific unit with 172:1 reduction ratio, 380 lb.-in. rated output torque and 3-in.-dia. splines. With input clamped, the wind-up angle at output is shown as a function of torque applied at the output.

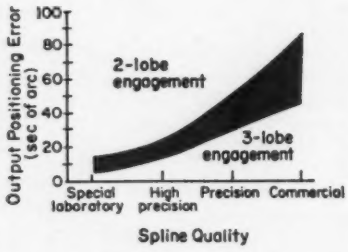



Fig. 16. Output positioning error (due to spline tooth placement) versus spline quality. The plot is based on a spline diameter of 4 in. or greater in a system of approximately 125:1 drive ratio.

isolation of two environments.

ROTARY-TO-ROTARY DRIVE—Use of the standard rotary-to-rotary arrangement for positive drive through a hermetic seal is shown in Fig. 9a. Here the flexible spline teeth are placed near the centre of a sealed cylindrical tube. The internal elliptoidal wave generator deflects the tube so that the flexible and circular splines engage at two regions on the major axis of the elliptoid. Since the numbers of teeth on the flexible and circular splines differ, rotation of the wave generator causes a reduced rotation of the output circular spline. With this system, rotary motions can be generated within a completely sealed vessel.

ROTARY-TO-LINEAR DRIVE—The method of rotary-to-linear transmission of motion through a hermetically-sealed wall represents a departure from the standard drive arrangement. Fig. 9b shows a sealed pressure envelope with flexible cylindrical walls surrounding a translatory, but non-rotating, lead screw with a circular cross-section. The inner wall of the flexible tube has annular grooves (threads of zero lead) and forms a flexible nut. The external wave generator, operating through anti-friction bearings, forms the flexible nut into an elliptoidal shape and deflects it into engagement with the lead screw at two diametrically opposite regions on the minor axis of the elliptoid.

To permit such engagement, lead-screw threads must advance one full thread per half revolution. That is, they must be double-lead threads. The general relationship for engagement of the flexible nut and lead screw is that the two have a difference in lead equal to, or an integral multiple of, the number of lobes on the wave generator. Thus, a two-lobe system can operate with a zero-lead nut and a double-lead screw as shown in Fig. 9b. Alternatively, the system can operate with a single-lead right-hand nut and a single-lead left-hand screw.

As the wave generator is rotated, the elliptoidal shape is advanced around the wall of the flexible tube. The flexible nut itself does not rotate but its elliptoidal shape does, causing the minor-axis regions of engagement to progress around the lead screw and produce translation of the screw. The direction of linear motion can be reversed by reversing the direction of wave-generator rotation. Linear actuators of high mechanical advantage can be made using this rotary-to-linear configuration.

### Performance Capabilities

The plotted performance curves in Figs. 10-16 are based on operational tests conducted on apparatus developed for the prolonged testing of rotary-to-rotary drives under accurately controlled load conditions. Independent measurements were made simultaneously on two drive units, tested interchangeably as speed reducer and speed increaser. Units have been driven for hundreds of millions of cycles, and their performance measured to better than 1 per cent accuracy. Additional comparative data have been taken from systems developed for special military and industrial applications.

Each of the graphs focuses attention on a particular physical or operational-performance parameter. A band of values is shown in most plots, ranging from conditions of standard design and manufacture to conditions of custom design and more exacting methods of manufacture. These broad curves are drawn about "design centre" values which are conservatively achievable today with standard systems. The design of any particular drive unit must represent a balancing of these various parameters.

United Shoe Machinery Corp.'s associated company, The British United Shoe Machinery Co. Ltd., are prepared to deal with any inquiries from companies in the United Kingdom (or elsewhere in the Commonwealth, excluding Canada) interested in possible applications of harmonic drive. Inquiries should be addressed to Mr. W. N. Bray (assistant managing director), at the British United Shoe Machinery Co. Ltd., Belgrave Road, Leicester.

*(To be continued in the March issue.)*

# PROBLEMS IN DESIGN

**Problem No. 12 (October): In a packet-filling machine, one feature comprises a reciprocating platen. This platen is required to reciprocate 6 in. to one side, then 6 in. to the other, with a variable dwell period at the mid-position. A 1,500-r.p.m. f.h.p. induction motor, continuously running, is to be used. Devise a suitable mechanism to achieve this.**

**Data: With no dwell period, the time for the complete cycle is approximately 2 sec. The dwell period at the centre position (variable while stationary) is from 0-5 sec., making a total cycle of 7 sec.**

Unfortunately, the majority of the entries received for the above problem were based on the incorrect assumption that, in one complete reciprocation of the platen, there should be two dwell periods. Had this been our intention, the full cycle time with two 5-sec. dwell periods would have been 12 sec. As this misapprehension was so general, however, we must consider ourselves partly to blame for not making the point clearer.

Despite the difficulties the problem presented, all the entries received showed great ingenuity. Very few, however, showed a grasp of the kind of basic rugged simplicity required of a production machine for packet filling.

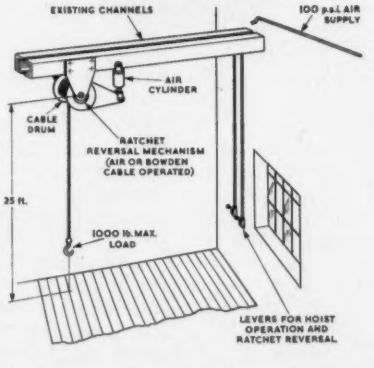
Dwell period mechanisms are fairly easy to arrange if they employ compressed air or hydraulics, or introduce electrical timing devices. What is much harder is to do the thing mechanically. All the entries we considered best came in this category. Among those providing for two dwell periods in the full cycle, we consider that from **H. B. Lancaster** to be very ingenious. He uses two right-hand-threaded lead screws geared together and driven by a spur gear on the shaft of the flange-mounted electric motor. Between the lead screws a double half-nut, made in the form of a pivoting bracket, is caused to travel backwards and forwards along a bar about which it can pivot through a few degrees as it engages first one and then the other lead screw. This pivoting action is brought about by two wedge-shaped cam blocks which come into contact with corresponding wedge-shaped projections, on each side of the double half-nut bracket, at each end of its travel. These wedge-shaped blocks are mounted on a left- and right-hand threaded rod, situated below the main lead screws, a handwheel being provided to enable them to be brought together or separated, according to the length of dwell period desired. The threaded dwell adjustment rod is provided with a 1:1 chain drive to a second left- and right-hand-threaded rod which carries two catch blocks, which are adjustable simultaneously with the cam blocks, and also a control output pin. The driven end of this second threaded rod is squared for driving purposes, and is capable of axial movement through the sprocket drive bush. The output pin is maintained in a central position by two opposed springs. A 4:1 output linkage is necessary to connect the mechanism to the reciprocating platen. The output catch blocks can be considered as a fork which is alternately moved from side to side by a projection from the top of the double half-nut bracket, the dwell period being accounted for by the period of time when the sides of the fork are not being engaged by the projection. As the cams for causing reversal of movement of the half-nut bracket are farther apart than the blocks which constitute the sides of the fork, by a fixed amount which never varies, the actual movement of the output pin is always the same.

To those who might object that a lead screw used in this way might give too sudden a reversal, Mr. Lancaster points out that the "pick-up" velocity on the 4 t.p.i. lead screws is only 3 in./sec., which is less than a centre lathe half-nut commonly encounters, mounted as it is in a heavy saddle which must be accelerated. Our only criticisms of this mechanism are that it is rather bulky and might be rather expensive to manufacture.

The diagrammatic perspective drawing from **A. Clifton** shows an ingenious double Scotch yoke mechanism for reciprocating the table. Although Mr. Clifton states in his description that there would be some form of spring-loaded location to prevent overshoot, in the bevel trains which drive the crank arms, it is difficult to see how this could be brought about. Unless disengagement of the roller arm on one side exactly coincides with the cam timing levers, there would seem to be a risk that at the centre position the two arms might get out of step by one gear tooth space. Apart from the clearly desirable kind of acceleration of the platen that this mechanism makes possible, it is interesting also on account of the timing device employed. It could be designed to give a dwell period on the forward stroke alone, as we had intended, or two dwell periods. The timing worm reduction drives, through a 3:1 spur gear train, the constant speed (20 r.p.m.) wheel of the friction drive unit. The variable-speed wheel of this unit is coupled directly to the variable profile cam. The lift angle of this cam can be varied from 180 deg., the position of no dwell between platen displacements, to 51 deg. 43 min., the position of 5 sec. dwell. The speed of cam rotation is varied by means of the friction drive unit, so that the cam operating time is 1 sec. The cam follower is spring-loaded in order to provide the necessary clutch operating load. By means of an adjustable cam setting scale, normally fixed to the rear section of the cam, the follower operating position can be set without any special cam lift form being required. The

**PROBLEM IN DESIGN NO. 16**

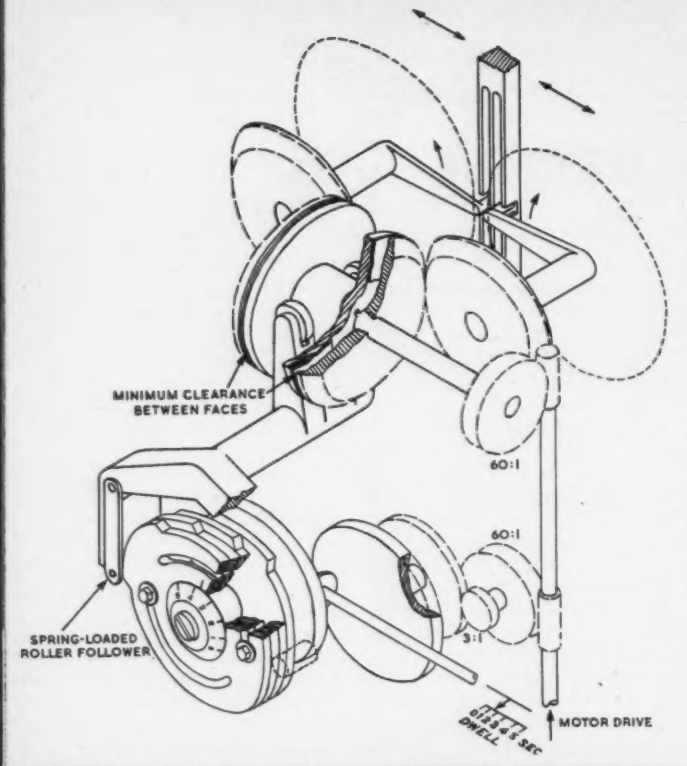
**Here is this month's problem**

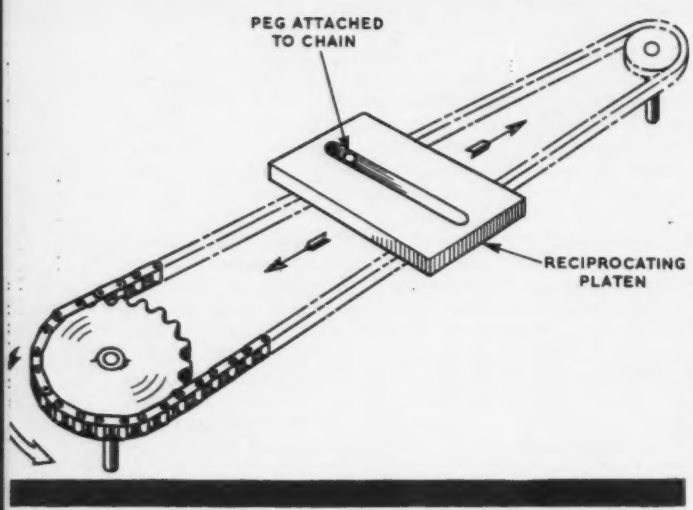



A works engineer's sketch of a hoist, to be operated by a single compressed air cylinder, is shown above. The device is wanted in a hurry at the minimum expense, without gears. No electrical controls are permissible.

Provide a more detailed scheme, embodying the main features, together with the air-line circuitry to be used.

*Best solutions to "Problems in Design" are published and paid for. Send your solution for this month, with a drawing or diagram (in Indian ink and not more than 12 × 12 in., please!), to the Editor, "Problems in Design No. 16 (February)". Closing date March 20.*




**A. Clifton**

(Upper diagram): A variable profile cam controls the engagement of two friction clutches whch alternately engage each crank arm of a double Scotch yoke and so bring about reciprocation of the platen.

Sketch of chain-type Scotch yoke mechanism.

cam plate next to the scale is adjusted to the dwell period required, and the intermediate cam plates positioned so that a continuous lift is obtained. The four plates are then clamped together to act as one complete cam.

**W. Brown** also took table inertia and acceleration very much into account, and provided a means whereby 0·2-sec. dwell increments could be provided. In Fig. 1 he shows how basic table movement can be obtained by the use of a four-slot geneva plate driving a crank via a 2:1 increase gear. The two slide bars attached to the table in conjunction with the crank plate form a Scotch yoke. Using a four-pin driver running at 1 rev. in 4 sec. to operate the geneva gives a basic table movement of 1 sec., with approximate harmonic movement and zero dwell, the table passing through zero velocity at the centre. At this stage if two diametrically opposite pins are removed the dwell becomes 1 sec., and if only one pin is used a dwell of 3 sec. is obtained without additional mechanism. In Fig. 2 Mr. Brown shows a novel form of geneva drive. In place of the four-pin driver, two driving plates flank the geneva plate, each being provided with twenty scalloped pockets. Roller guides shroud part of these plates, and suitable rollers are retained in a magazine. An endless triplex chain loop is mounted on a twenty-tooth double sprocket engaging the outer runs of the chain, and cam blocks are mounted as required on the middle rim of the chain. This twenty-tooth sprocket is driven at the same speed as the geneva driver, and a tappet is interposed to elevate the rollers to engage with the pockets in the driving plates. Since the chain speed is 5 pitches per sec., if a cam is placed in every fifth pitch the dwell will be zero. For a dwell of, say, 3·2 sec. there will be twenty-one pitches between the cam blocks. For convenience in building up chain length, the chain loop would be forty-two pitches with two equi-spaced cam blocks. Our only criticism of this very novel entry is that the crank disc would be rather large, and fitting the cam blocks might be a little tiresome. We are surprised that the chain type of Scotch yoke for reciprocating a table or other device was not among the entries sent in (see sketch). It was used years ago for operating windscreen wipers on the large windows of buses, and is a simple device which works well.

The schematic layout from **J. W. B. Clayton**, although clearly impractical if taken literally as drawn, embodies certain novel features, notably a space cam, which gives it considerable development potential. A pair of cone pulleys, having a ratio of 3·5:1, provide the drive to a three-start worm which engages a worm wheel. The worm wheel is attached to, or forms a part of, a cam of special design, spring-loaded against which is a traversing rod or cam follower. This rod actuates the lever which, in turn, reciprocates the platen. The bracket which supports the traversing rod is capable of linear movement across the face of the cam, this being achieved by means of a hand-wheel and screw. The cam profile is designed to be operative in two dimensions—for constant 12-in. throw in one dimension for the platen, and for an infinitely variable time period of dwell in the other dimension, for 0-5 sec., with a total cycle of 7 sec. on maximum dwell and 2 sec. total cycle when on zero dwell. An advantage of this mechanism is that it could be adjusted while the mechanism was running. Although a ball-ended cam follower with a spring return appears an unlikely idea to use, it might be possible to produce a space cam with followers on each side, and so give a more positive drive.

To summarise this commentary is difficult. As stated at the outset, the easy way out of this sort of problem is to use an air or hydraulically driven device or, alternately, to incorporate time switches and electrically-operated clutches. **T. J. Kill** sent a pneumatic or hydraulic version, while **I. C. Addis** and **V. J. G. Harding** both sent ingenious entries using electro-magnetic clutches.

**H. B. Lancaster**

Two right-hand-threaded lead screws, geared together and continuously driven, reciprocate a pivoting double half-nut. Length of dwell period is controlled by the relative distance apart of the catch blocks and push-over cams which are simultaneously adjustable by a hand wheel. Movement of catch blocks operates output pin to which platen linkage is attached.

**J. W. B. Clayton**

Worm and wheel mechanism traverses cam follower across the face of a cam of special design. The cam profile is operative in two dimensions, dwell period being controlled by radial position of cam follower.

**W. Brown**

Fig. 1 shows how basic table movement can be obtained by the use of a four-slot geneva plate driving a crank via the 2:1 increase gear.

Fig. 2 illustrates a roller magazine variant of the geneva drive, this to be operated by a cam attached to a continuous triplex chain drive.

Sports car door being made by the wet lay-up process, using polyester resin and glass mat.

# LAMINATES WITH INORGANIC FILLERS

*Laminates made with asbestos, glass and metal fillers are compared, and a survey made of their properties and uses*

by R. PEMBERTON *

INDUSTRIAL laminates, which were among the first really successful applications of plastics in industry, were originally developed to provide the electrical engineer with a strong, rigid, insulating material. For this purpose, they incorporated paper or cotton fillers which more than adequately provided the properties then required. Today laminated materials are required to perform much more exacting tasks and, although the more traditional grades still constitute a very large proportion of overall sales, increasing use is being made of newer types of fillers—principally based on inorganic substances.

For all practical purposes, inorganic laminates are based on either asbestos or glass, although there are other inorganic fillers used in laminates, principally certain forms of metal, of which more will be said later. These fillers, like their organic counterparts, are capable of being treated satisfactorily with several resins such as phenolic, melamine, epoxide, silicone, polyester and polytetrafluoroethylene (p.t.f.e.) to give impregnated or coated materials suitable for making laminates with a wide range of properties.

Bearing in mind that fillers like asbestos and glass are available in different forms, each of which can be based on different fibres, it will be seen that many inorganic filler-resin combinations can result in a variety of different products, each of which has its own particular properties. Before going into detail about these, however, a brief mention is first made of the different forms, properties and method of manufacture of the fillers themselves.

* *Research and Development Department, Bakelite Ltd.*

### Asbestos

Asbestos is the name applied to a group of fibrous minerals which occur chiefly in Canada, the U.S.S.R. and South Africa, though small amounts are found also in many parts of the world. The most common form is chrysotile asbestos, a hydrated silicate of magnesia. This is usually found as veins in serpentine rock, and often occurs in the form of a mass of fibre bundles which vary in length from a fraction of an inch up to 2 in. The fibres are split by a crushing process before being separated, cleaned and graded by means of various screening processes. Using conventional machines the fibres can be converted into either paper, felt or yarn, of which the latter can, in its turn, be converted into woven fabric. It is common practice to add a proportion of organic fibre such as cotton or viscose rayon to facilitate conversion into whatever form is required.

### Glass

Glass, like other fillers, is available in various forms, and the type chosen has a direct bearing on the electrical properties of the end-product. There are broadly two classes; viz.: electrical or E glass, and non-electrical glass. The former is a low-alkali borosilicate glass, whilst the latter includes the lime soda glasses with a relatively high alkali content. Where good electrical properties and water re-

sistance are prime requisites, E glass is the preferred choice. Non-electrical glass is cheaper than E glass, and is frequently used with polyester or epoxide resin for mechanical applications.

The glass fibres are spun into yarn, in either staple or continuous form, the continuous form being preferred for laminates, since it results in better tensile strength in the finished laminate. These fibres are converted into either rovings or non-woven mats or woven fabric; the non-woven mats are employed primarily in the manufacture of wet lay-up laminates, and the woven fabrics in the production of conventional dry-ply laminates. (Further information about these methods of laminate manufacture is given later.)

In order to facilitate the production of woven fabric, it is necessary to coat glass fibres with size, but, since this size generally hinders the keying of the resin to the fibre, it is usually removed in whole or in part after weaving. The removal is usually accomplished by a chemical washing or by a heat-treatment process. Additionally, special finishes may be given to the fabrics by further chemical treatments in order to achieve a more satisfactory resin-to-glass bond. These finishes are, in effect, chemical bridges by which the resin can be more closely linked with the glass.

### Metal

Metal fillers take the form of either wire gauze, foil or sheet. The wire gauze employed is usually of steel or aluminium, whilst the foil or sheet is usually of aluminium to maintain the weight advantages offered by plastics. Examples of some typical properties of inorganic fillers are given in Table 1.

*Table 1. Some typical properties of inorganic fillers in fibre form*

| Filler | Asbestos (Chryso-tile) | Glass | Metal | |
|---|---|---|---|---|
| | | | Aluminium alloy | Steel wire |
| Specific gravity | 2·5 | 2·5 | 2·7 | 7·8 |
| Tensile strength (p.s.i.) | 90,000 | 220,000 | 13,000–40,000 | 300,000 |
| Maximum operating temperature (°C.) | >350 | 380 | 135 | >350 |
| Electrical insulation | poor | very good | material is a conductor | |

### Manufacturing Inorganic Laminates

Turning for a moment from the preparation of the fillers to the manufacture of the inorganic laminates themselves, there are essentially two methods:

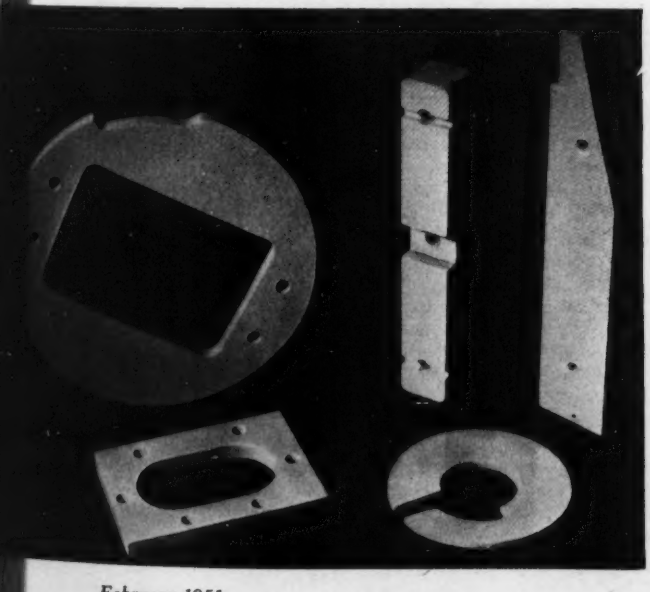
1. Wet lay-up
2. Dry lay-up or dry-ply.

In *wet lay-up*, a solventless resin is applied to a sheet of glass mat or fabric, either by pouring on the resin or spreading it on with a spatula or roller. The resin layer is then covered with another sheet of mat or woven fabric, and a fresh application of resin given to the second sheet of filler. The process is repeated and continued with alternate applications of resin and filler until there are sufficient layers to give the required thickness of laminate. The assembly is cured in a press, or *in situ*, usually without the application of external heat. The method is used principally with polyester resins and to a large extent with epoxide resins.

The *dry-ply* method involves impregnating cloth with a liquid resin or resin in solvent solution. The treated fabric is then dried, thereby removing the solvent to give a dry impregnated material, in which the resin is still capable of flow when heat and pressure are applied. Sheets of impregnated material are then cut to size to suit the mould or platen, the actual number of layers of impregnated cloth determining the thickness of the finished laminate.

In the wet lay-up method, the laminate can be cured with or without the application of heat and with or without pressure. In dry-ply laminating, pressure accompanies the application of heat. Cure temperatures vary according to the resin and process used, and range from 70-250 deg. C.; cure pressures vary between contact pressures of less than 15 p.s.i. up to pressures as high as 2,000 p.s.i.

Control gear components made from silicone resin bonded glass fabric laminates.



### Properties and Uses of Laminates

For the sake of convenience, the properties and uses of the laminates are grouped according to the filler used, but, before dealing with these individual groups, attention is drawn to one property which, as a class, is possessed by all laminates based on inorganic fillers. This property is heat resistance.

The actual degree of heat resistance will, of course, depend to a large extent on the actual resin binder used, e.g., a silicone-glass laminate will generally withstand more heat than a glass laminate bonded with epoxide resin. Further, in choosing a material for any application demanding heat resistance, one must also take into account other relevant factors such as the presence of corrosive chemicals or the presence of excessive moisture in the atmosphere.

Nevertheless, in order to give an indication of the degree of heat resistance of materials, it is now often the practice to classify them according to BS 2757. By this specification, materials are classified with a letter Y, A, E, B, F, H or C according to the particular temperature (range 90-180 deg. C.) the material is considered capable of withstanding under usual industrial conditions.

Of particular interest at the present time are materials capable of meeting Class H or C applications, i.e., materials to withstand 180 deg. C. and above 180 deg. C. respectively.

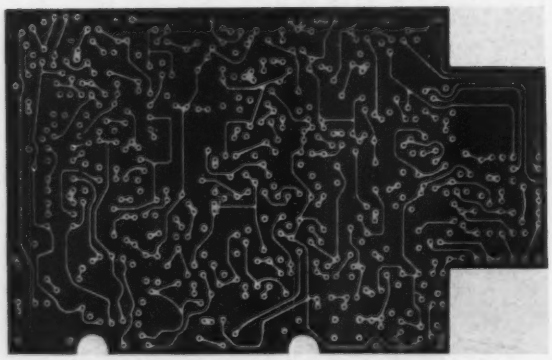
### Asbestos Laminates

Laminates based on asbestos are usually bonded with phenolic resin, although asbestos laminates have also been produced from melamine and silicone resins. Asbestos laminates are used principally in applications demanding high heat resistance. As mentioned earlier, asbestos is available in fabric, felt or paper form, and laminates can be made from all of these. In addition to heat resistance, the laminates have good mechanical properties. Whilst most properties of both paper- and fabric-filled asbestos laminates are similar, the impact strength of the fabric-filled material is usually higher than that of the paper-filled form.

Naturally, uses of laminates vary. One use particularly worth mentioning is that of bearing cages, where woven asbestos laminates have proved to be a very satisfactory material. Asbestos paper laminates, which as stated earlier contain a proportion of organic fibres, usually meet applications demanding resistance to sustained temperatures of 130 deg. C. and resistance at intermittent temperatures of up to 150 deg. C. These materials, therefore, meet Class B of BS 2757, and can in some cases be said to meet Class F.

The felt asbestos laminates are primarily of the low-pressure type. These laminates have high impact strength in addition to heat resistance, and find uses in the aircraft and textile industries, for applications such as drop tanks for aircraft fuel, glider wings and textile bobbins.

Woven glass fabric after impregnation with resin, being reeled prior to being cut into sheets for laminating under heat and pressure (dry-ply process).



Printed circuit made from copper-clad epoxide-glass laminated sheet.

### Glass Laminates

Whilst asbestos laminates satisfactorily meet many heat resistance requirements, there are still applications which can only be satisfied by glass laminates. Dependent on the particular resin-glass combination, this group of laminates provides a range of materials in which heat resistance is coupled with good mechanical and/or electrical properties. Glass laminates have been produced from most resins, in particular from phenolic, melamine, epoxide, silicone, polyester and p.t.f.e. resins, and these are detailed below:

PHENOLIC GLASS LAMINATES—These are available in high- and low-pressure forms. They have good resistance coupled with good mechanical properties including impact strength. Post-curing is sometimes given to phenolic glass laminates in order to develop heat resistance and improve mechanical properties.

MELAMINE GLASS LAMINATES—In addition to good heat resistance, melamine glass laminates have good dielectric strength, arc resistance and mechanical properties, including impact strength. Melamine laminates are now available with good water resistance and electrical properties which are retained at temperatures as high as 200 deg. C.

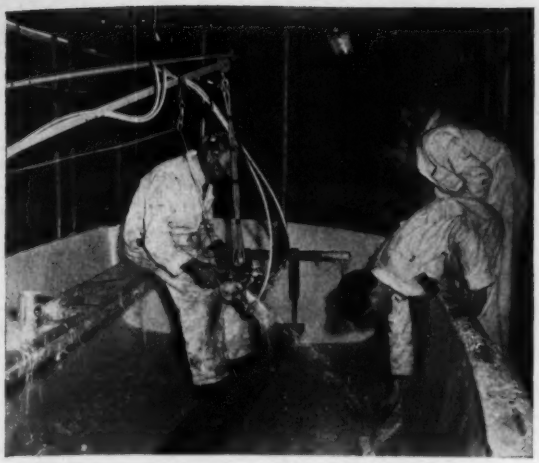
EPOXIDE GLASS LAMINATES—Uses of these relatively new laminates are increasing rapidly and appear to be largely connected with Services requirements, particularly in guided missile applications. This is due principally to their good water and chemical resistance and their excellent mechanical strength. In addition, they have good dimensional stability under conditions of varying humidity. They can be made by both the wet lay-up and dry-ply techniques, the choice of manufacturing method being largely dependent on the resin-hardener combination being used as a binder. Again, wet lay-up is often used when making epoxide glass shapes, whereas the dry-ply method is normally employed in the production of flat sheets; these latter are now being produced in increasing quantities, particularly in the copper-clad form.

Choice of hardener has an appreciable effect in achieving particular properties; e.g., use of H.E.T. anhydride results in a laminate with self-extinguishing properties. The excellent strength of epoxide laminates has also resulted in uses as diverse as lorry cab structures, boats and polo stick shafts, whilst their chemical resistance has led to their use in extraction fans, ducting and tanks for plating solutions.

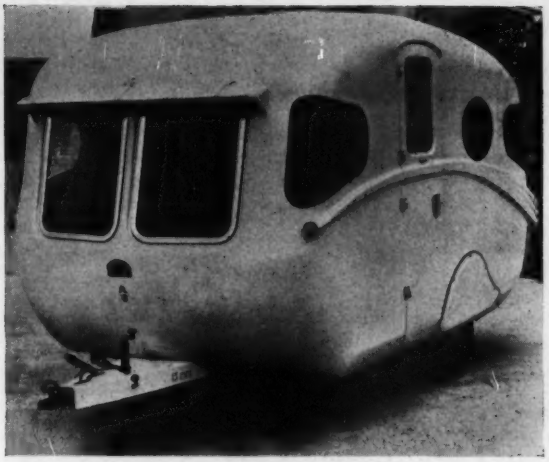
SILICONE GLASS LAMINATES—Silicone glass laminates are noted principally for their exceptional resistance to high temperatures. Since they are suitable for continuous use at temperatures as high as 180 deg. C., and sometimes above this, they are often used for Class H applications. Coupled with heat resistance are very good water resistance, good electrical insulation and low power factors at high frequencies.

Manufacture of silicone laminates is by the conventional dry-ply technique. Impregnation of the glass fabric is usually with catalysed resin, catalyst and pre-cure (or drying time) being varied to suit the pressure at which the impregnated materials are moulded. Once the laminate has been moulded, it has to be post-stoved in order to develop fully the good mechanical and electrical insulating properties of the resin. This post-stoving is usually carried out at temperatures up to 250 deg. C. in electrically or gas heated ovens, the duration of the post-stoving varying from a few hours for very thin sheets to many hours for thick laminates.

As stated earlier, silicone glass laminates function satisfactorily at high temperatures, and their uses, therefore, are largely those which call for this property coupled with good electrical properties; e.g., as structural insulating material in transformers insulated to Class H specification,



Spraying polyester resin and chopped glass from a Rand gun on to the inside of an epoxide-slate-glass mould.



Caravan shell and chassis moulded from polyester glass fibre material.

and parts such as terminal blocks and switchgear of electrical appliances expected to develop temperatures nearing 200 deg. C.

POLYESTER GLASS LAMINATES—This class of laminated material is used primarily for mechanical applications, electrical properties being of secondary importance. As a class, polyester glass laminates are very strong and they have good water resistance. The ease of manipulation afforded by wet lay-up has led to a widespread use of polyester glass laminates in the manufacture of a variety of mouldings of different shapes and sizes, including motor car and caravan bodies, boat hulls, protective helmets, typewriter cases and outside shells of refrigerators. By the addition of appropriate filler to the resin-hardener mixture, many polyester laminate grades have been developed which have special properties to meet specific applications; e.g., fire-resistant laminates can be made self-extinguishing by the addition of antimony trioxide. An alternative way of making polyester laminates self-extinguishing is by the use of resins based on chlorinated acids.

An interesting feature in recent years has been the coloured mouldings achieved by the addition of inorganic pigments or pigment lakes to the resin hardener mixture.

P.T.F.E. GLASS LAMINATES—Fluorinated hydrocarbons, of which p.t.f.e. is probably the most well known, have very good heat resistance and easily meet Class H requirements. In addition, they have excellent dielectric properties, water and chemical resistance, all of which are maintained at high temperatures. The very high cost of this inorganic laminate, however, has to date prevented widespread development of this material. Nevertheless, interest in p.t.f.e.-glass laminates is growing, and a typical application in which this material has been used is in the lining of storage tanks in which corrosive solutions are kept at high temperatures.

In order to amplify the general statements made about asbestos and glass laminates, typical figures for the more common properties of these materials are given in Table 2.

### Metal Fillers

Finally, as mentioned earlier, some laminates incorporate metal fillers, principally steel, aluminium wire, gauze, aluminium sheet or foil. The advantage of laminates incorporating wire gauze is that an improvement is obtained in impact strength. Satisfactory use of this type of reinforced laminate has been made in public service vehicles, where good impact resistance is a constant requirement.

Aluminium in sheet form may be used in the manufacture of decorative laminates. These laminates are usually,

*Table 2. Typical properties of some laminates with inorganic fillers*

| Laminate: Resin | Phenolic | | | Melamine | Polyester | Silicone | Epoxide |
|---|---|---|---|---|---|---|---|
| Filler | Asbestos | | Glass | | | | |
| | Paper | Fabric | | | | | |
| Cross-breaking strengths (p.s.i.) | 20,000 | 12,000 | 28,000 | 24,000 | 30,000 | 25,000 | 60,000 |
| Insulation resistance (megohms) | 10 | 0·5 | 2 | 400 | 5 | 4,000 | 2,000 |
| Electric strength at 90°C. Normal to laminate (V./mil.) ($\frac{1}{16}$ in. thickness) | 50 | 15 | 50 | 220 | 210 | 240 | 250 |
| Parallel to laminate | 3 | 1 | 10 | 30 | 35 | 40 | 45 |
| Power factor at 800 c/s | — | — | 0·05 | 0·03 | 0·08 | 0·010 | 0·025 |
| at $10^6$ c/s | — | — | — | 0·015 | — | 0·003 | 0·025 |
| Water resistance | very good | good | good | very good | very good | excellent | |

*Note: Test methods as BS 2782 Pts. 2 and 3 (1957), and Pt. 5 (1958), as appropriate.*

in effect, aluminium surfaced with a thin decorative laminated paper-filled veneer, i.e., the aluminium content is much greater than the plastic content. This type of laminate can be used as an unsupported structural panel, particularly in applications where fibre resistance is a consideration; e.g., in the construction of ships' cabins. Aluminium foil is often incorporated just below the surface of a decorative laminate in order to dissipate heat caused by local hot spots (such as would be caused by a burning cigarette) and thus prevent blistering or other damage.

Before concluding this section on metal fillers, mention is made for the sake of completeness of one other metal which is being used in the foil form in increasing quantities, namely, copper foil. This material is used as a surfacing layer in the production of copper-clad laminates, the foil thickness being usually 0·0015 in. These laminates, which can be based on paper or on glass fabric fillers, are used widely in the production of "printed" electrical circuits.

### Conclusion

In this brief article an attempt has been made to compare various laminates based on inorganic fillers, and to give a general survey of the comparative uses and properties. Although in general these laminates are inclined to be expensive, there is a noticeable trend to lower costs, helped in some measure by the increasing use of glass mat. It is probably by an extension of the use of this form of reinforcement that we can look for still further economies, and, in consequence, more general usefulness and a truly structural (load-bearing) laminate.

# SEAL MATERIALS FOR HIGH TEMPERATURES

A RECENT report* introduces novel rotating seal materials, developed and tested under conditions of no external lubrication, for potential aircraft applications at high speeds and high temperatures. These materials were selected after a systematic study of the wear behaviour of: pure refractory hard metals; binary alloys of pure refractory hard metals, bonded with nickel; and ternary alloys of pure refractory hard metals, bonded with nickel and infiltrated with silver.

While it is true that, generally, the present materials used for such seals are satisfactory, the evidence indicates that they are operating near their upper temperature limits, with a minimum margin of safety. At present the only lubricants available break down at temperatures over 315 deg. C. Therefore, it was necessary to study surface reactions between two components at high speeds and high temperatures, without using external lubrication.

In order to determine basic information for future aircraft operating conditions, the seal material was tested at: (1) ambient temperatures up to 730 deg. C.; (2) sliding speeds of 30,000 ft./min.; (3) loads up to 14 p.s.i.; and when (4) no liquid or powder lubrication was used on the surfaces.

Seal materials for aircraft applications were screened to determine wear mechanisms at speeds of up to 30,000 ft./min. at loads of 14 p.s.i., with no liquid lubricant under accelerated test conditions. The following results were obtained.

### Results

1. Wear studies of certain brittle pure refractory hard metals, i.e., $VB_2$, $VSi_2$, $WSi_2$ and MoB, indicate that they have fairly low wear rates against both tool steel and Inconel. However, they are too brittle for consideration in most applications.

2. Alloys composed of nickel and refractory hard metals are not satisfactory.

3. Several ternary alloys containing a high percentage of refractory hard metal, i.e., WB, CrN and MoB, with a nickel matrix for toughness and infiltrated with silver as a lubricating phase, appear satisfactory for further consideration as seal materials.

4. Excellent results are obtained from a combination of tool steel and an alloy of 90 per cent WB, 10 per cent nickel (silver infiltrated), at speeds of 29,000 ft./min., no lubrication, load 14 p.s.i., and temperatures up to 565 deg. C. It is possible to vary the composition of the WB alloy by a considerable amount and still retain the superior wear qualities.

5. An alloy composed of 60 per cent CrN, 20 per cent nickel, 20 per cent silver offers very good wear properties with tool steel, and good wear rates against Inconel. Reaction films formed on the surface of the WB and CrN alloy furnish excellent low wear rates.

6. When high temperatures are reached, the silver phase plastically deforms. Therefore, the energy needed for the shearing action at the surface layers is required at a smaller rate, and as a result the coefficient of friction is lowered.

7. Tool steel is limited to temperatures up to 565 deg. C. Inconel may be too soft for top temperature performance.

8. Consideration should be given to the use of an alloy containing a high percentage of WB, silver-nickel; or CrN, silver-nickel; for sliding against a material which retains its hardness at high temperatures, such as stellites or Inconel X.

9. There appears to be no single physical property such as hardness, structure, melting point, etc., that aids in discerning proper formulation of a high quality sealing material for these applications. Metallographic studies are only one tool necessary in determining the correct alloy. Phase diagrams are not available in the literature for alloys consisting of nickel and refractory hard metals. Even if phase diagrams were available for alloy construction, it would still be necessary to determine the various oxide structures formed on the surface by electron diffraction or other methods, in order to ascertain fully the reasons for excellent wear patterns in one instance and poor or worthless wear results in other cases. An investigation such as this, coupled with regular wear tests, would prove beneficial in determining the fundamental reasons for the wide variation in wear at high temperatures.

10. Since no liquid lubrication was used in these tests, it was necessary to add substances to the refractory hard metal for the purpose of developing an alloy which would react with the mating surface to form various complex oxides or nitrides. These compounds furnish a solid lubricating film, which in turn reduces the surface friction and eliminates galling, seizing and pitting to give the desired mild wear and sealing properties. The solid lubricating film formed in this way is continually replenished, whereas any liquid or powder type lubricant suffers from the disadvantage that it must be constantly supplied.

11. The testing of impregnated graphite seals and zirconium-coated graphite seals when either impregnated or unimpregnated was a relatively minor phase of the test programme. The best wear values are those obtained when a carbide-coated unimpregnated graphite disc is used. However, additional studies are required to establish the trend indicated here by the limited amount of data.

12. Kentanium (a hard titanium carbide alloy made by Kennametal Inc.) run dry against Kentanium furnished the finest results at sliding speeds of 14,000 ft./min. at elevated temperature.

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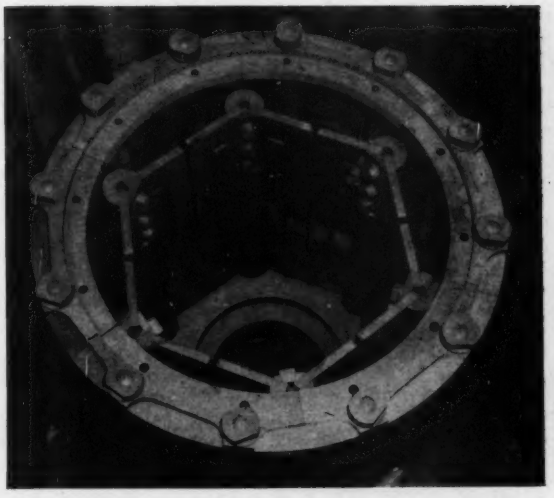
* *Prepared by Horizons Inc., Ohio, at the Wright Air Development Center.*

# NEW FURNACE OPERATES AT 3,100 DEG. C.

*A recent development allows furnaces to be operated at higher temperatures than were hitherto possible*



A furnace at Harwell. (Photograph by courtesy of the United Kingdom Atomic Energy Authority.)

ELECTRICALLY-HEATED resistance furnaces suitable for temperatures up to 3,100 deg. C. have been developed by The General Electric Co. Ltd., and the Atomic Energy Authority, Harwell. The heart of each furnace is a graphite resistor which, unlike other materials, increases in tensile strength as temperature rises. The resistor is also chemically stable up to 3,000 deg. C., and as its temperature coefficient of resistance is small, the electrical gear can be comparatively simple. It is necessary to use an inert atmosphere such as argon to protect the graphite while it is hot.

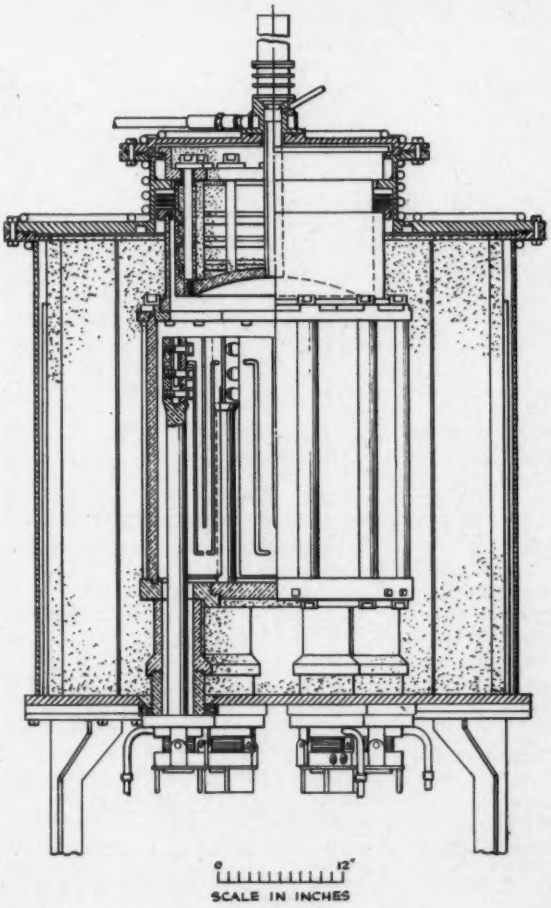
The general construction of such a furnace is shown in the accompanying diagram. This furnace is rated at 200 kW., and has a charge space 24 in. high by 15 in. diameter. The element consists of a set of graphite plates bolted together to form a hollow hexagon 2 ft. 6 in. high, with sides of 12½ in. Each plate is partly cut down the middle to form an extended current path.

Power is fed to the resistor through six graphite connecting rods which pass vertically through the bottom of the furnace tank. This tank is made from mild steel. It is of vacuum-tight construction, and has a flexible inner lining of stainless-steel sheets to take care of the differential expansion which takes place over an integrated mass such as a furnace wall where the temperature of the inner face is about 3,000 deg. C., and that of the outer face 100 deg. C. The carbon black heat insulation is confined within the limits of the flexible stainless-steel sheets and a graphite inner wall made up of graphite plates which are bolted together. Loading of the furnace is effected through the roof, which incorporates a removable plug-type lid consisting of a graphite shell filled with lamp black.

The elements operate at low voltage, and are fed from the secondary of a three/six-phase regulating transformer which can be steplessly adjusted between 5 and 20 V. while on load. A total radiation pyrometer sighted on the element feeds a signal to a control instrument, which in turn adjusts the transformer setting to hold the required temperature.

Primarily, the furnace was designed to assist in the study of the production of high quality graphite. Purity of atmosphere was essential, so 99·9 per cent purity argon was used. To economise when purging, a technique has been developed of evacuating the tank twice, alternating with nitrogen filling; a third evacuation and final filling with argon ensures almost complete removal of oxygen and carbon dioxide from the furnace tank before heating up is commenced.

While the furnace is in operation, the argon is circulated at a rate of about 200 cu. ft./hr. through the furnace chamber and insulation. The pressure within the chamber is about 18 p.s.i. gauge. The gas is purified by passing through a train in which the carbon monoxide and hydrogen are converted to carbon dioxide and water vapour, and then removed by caustic soda drier beds and activated alumina towers.




This article was prepared by members of the staff of The General Electric Co. Ltd., of Erith, Kent.

# INFLUENCE OF DESIGN ON HEAT-TREATMENT STRESSES

*This article shows how component design, together with quenching technique, can influence the magnitude of any internal stresses which may be induced during heat-treatment, generally from the quenching operation*

**Abridged version of an article by A. G. GARDNER, A.I.M.** *

The failure of heat-treated steel components may be the consequence of one or both of two factors: (a) internal stresses induced during fabrication or heat-treatment; and (b) external stresses applied in service. Internal stresses induced during heat-treatment may be great enough to exceed the strength of the material, in which case cracks or complete fracture will occur. Alternatively, although the internal stresses may not be great enough to cause failure during heat-treatment, they can represent the greater part of the material strength, and failure can then occur in service under a relatively light load.

The process of heating or cooling is associated with temperature gradients and consequent volume-change gradients. These thermal gradients are accompanied by structural changes which also produce volume changes, and the overall result can be the generation of high residual stresses. The temperature gradients arise because cooling is not even throughout the mass of a part which is being quenched, and depend largely on the size and shape of the piece. The aim, therefore, should be to design in such a manner as to keep temperature gradients to a minimum.

### Effect of Shape on Cooling Speed

The ideal condition from the design point of view is attained when the entire piece can be heated and cooled at approximately the same rate during the quenching operation. This can rarely, if ever, be achieved, but much can be accomplished by careful study. The greater the temperature difference between any two points on or in a given part during quenching, and the closer these two points, the greater the internal stress and, therefore, the poorer the design.

A component taken from the furnace in readiness for quenching is at a uniform temperature, provided it has been given sufficient soaking time, but as soon as quenching begins the temperature is different in almost every part of the component. This arises because of two factors:

1. The heat capacity of some portions is greater than that of others, simply because there is more metal in one portion than another.
2. The shape of the surface affects the cooling rate. Fig. 1 shows a shape which, although of uniform thickness, will not cool uniformly. Protruding corners, such as at A, are cooled from three sides, so that the extreme corner gives off heat from an area approximately seven times as great as that through which it is receiving heat. An edge, such as B, is cooled from two sides, and the ratio of the area through which it is giving off, and that from which it is receiving, heat is 3:1. A point on the flat side, such as C, receives heat from one side, and gives it off from the other. Here the cooling and heating areas are approximately equal. At the re-entrant angle D, heat is being supplied to the surface through an area three times as great as that through which it is being dissipated, and this point will cool slowly.

Sharp re-entrant angles are always objectionable, since it is impossible to obtain uniform cooling during quenching in the immediate vicinity of such an angle. Consequently, heavy internal strains are set up at a point which will almost certainly be subjected to stress concentrations in service. In fact, it can easily happen with an indifferent design that high local stresses induced in service are concentrated at points already weakened by internal stresses produced during hardening.

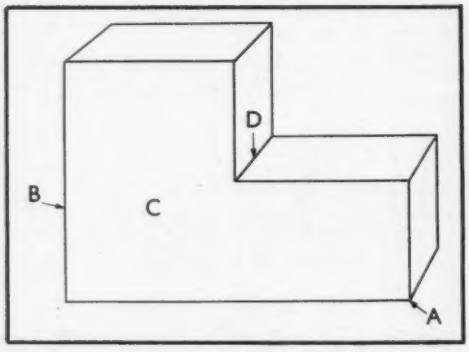



Fig. 1. Shape of uniform thickness which will not cool uniformly.

### Designing for Heat Treatment

The foregoing has been concerned with the manner in which internal stresses can occur during cooling. It is next necessary to consider certain features of design which can be used to minimise heat-treatment stresses, and this is best achieved by quoting some actual examples.

There are various ways of overcoming the problem of sharp re-entrant angles in large and heavy sections. Holes can often be provided through a heavy portion in order to balance the weight of the metal throughout the component. At the point of the re-entrant angle a generous fillet can be provided or, alternatively, under-cutting can be adopted to provide a radius while still obtaining the effect of a sharp corner. The latter method has little to recommend it from the standpoint of quenching stresses, but in service the concentration of stresses, such as would occur at a sharp corner, is avoided.

As regards keyways, a round-cornered form is to be preferred. Two keyways cut on opposite sides of a ring almost

* The original article appeared in *The Wild-Barfield Heat-Treatment Journal.*

invariably cause it to become oval on quenching. The section can be balanced by cutting two further keyways at right angles to the first pair and thus preventing warping. Keyways in a splined shaft may cause distortion in quenching. Unless designed with ample section, a shaft with a keyway has less stiffness than one carrying keys integral with the shaft. To minimise distortion in quenching, it is advantageous to have more than one integral key. These keys are spaced about the shaft to facilitate equal cooling and to balance the section.

When heat-treating heavy forgings, large radii or fillets should be provided at sharp changes of section so as to minimise the danger of cracking. As sections increase in size or as shapes become more irregular, the possibility of quench cracks increases. The effectiveness of quenching a bored forging depends to a great extent on the ratio of wall thickness to the diameter of hole and the length.

Carbon steels are not recommended for complicated shapes where distortion must be avoided. For complicated shapes water quenching should not be used, and a less active quench employed which reduces the temperature gradient considerably during quenching. Some parts which have very abrupt changes of section are almost impossible to harden, but there is a certain amount of latitude when oil-hardening or air-hardening steels are quenched, because of the lower temperature gradients. Thus a design which is satisfactory when the part is made from an air-hardening steel may be quite unsuitable if a steel requiring a more drastic quenching medium is substituted.

In steel that has been carburised the volume changes that cause internal stresses are further complicated by the fact that the high carbon case changes much more in volume while passing through the transformation range than does the low carbon steel in the core, and the temperature at which the change in volume occurs varies greatly with the content of carbon and alloying elements. In these cases it is necessary to carry out trials to determine the best combination of case depth and method of hardening which will leave the component in the most favourable stress condition, to meet service requirements. Normally, the volume increase that occurs when the case hardens is greater than the increase in the core. The carburised case is then in a state of compressive stress and this condition makes it possible for the part to sustain a higher external load (which generally tends to create tensile stresses) than if compression stresses were not present.

Compressive stresses generated in the case of a carburised component are opposed by equivalent tensile stresses in the core. If the cross-section of the core is insufficient to support the compressive stresses in the case, then failure occurs in the core. This failure sometimes takes place as transverse cracking through the core and in other instances by cracking between the case and the core, causing a separation at the bottom of the case. As smooth a transition in hardness as possible should be aimed for from case to core in order to avoid stress concentration at the boundary.

# DESIGNING FOR COLD EXTRUSION

THE recent conference* held by The Institute of Sheet Metal Engineering on the cold extrusion of steel admirably underlined the problems and possibilities facing those associated with this process. Information for the component designer, however, was notable by its absence. The reason for this becomes obvious when it is realised that the success of a component produced by cold forging is dependent primarily on the skill of the tool designer, and to a lesser degree on the machine and its operator.

Considerable research on tool design and operation is being carried out at the Production Engineering Research Association, the National Engineering Laboratory and the Royal Ordnance Factory, the latter producing first-class components using methods derived from theories backed by photo-elastic studies and past experiences. From an economic viewpoint, die life and the quantity of components required are of paramount importance, and are largely influenced by the mechanical properties desired in the components, and also by the organisation at the particular company concerned.

The British Motor Corporation are probably unique in that their machine shop costs are very low due to considerable experience in automation. It follows, therefore, that the dimensional limits necessary in order that the forged components will be comparable to machined components will be considerably tighter than those required in other industries, where machine shop costs are higher.

A further aspect is the capital cost involved for a cold forging plant. Is it more economical to have a cheap machine designed for the specific production of a single component, or to have a more expensive plant which is universal and can be adapted to other designs? The former solution may be suitable for a company such as the B.M.C., but not necessarily appropriate where smaller numbers of components are required in a wider variety.

It is generally agreed that, whether a 20-ton or 70-ton steel is used, the final strength of the cold forged component will be of the same order, i.e. about 70 tons, the increase of the lower figure being due to cold working. While this assertion has been proved by tests at B.M.C., it does not explain the phenomena sufficiently well for a designer to predict with any degree of reliability the ultimate performance of a component.

The British Standard Specifications appear to be left wide in order to cover the best and the worst of the steels produced. This impression is strengthened by the number of delegates at the Conference who accepted the fact that it did not really matter what the strength of the material was initially, since it all became the same after heat treatment, prior to forging. This disregard for the properties of the material provides a dismal outlook for the designer, who in the majority of cases looks first for the properties.

A cold forging process in which strip is used instead of a slug may be of even greater significance to the designer—this process was described by Prof. Dr. Ing. O. May. Many examples of intricate design are possible, the most useful probably being those where studs or stems are raised integrally from the strip.

Curiously enough, the corner between the stem and the strip must be sharp, which again underlines the fact that the designer of the component is very much in the hands of the tool designer, who relies almost entirely on experience. A further example of this is where piping was continually occurring in a forging. This defect was eliminated simply by degreasing the tools and the part by wiping with a cotton rag prior to the last operation.

The correct type of lubricant is of great importance to the finish of the product. Without it the mechanism of forming becomes internal shear, rather than plastic flow of metal.

The rate of deformation is relatively unimportant in normal backward and forward extrusion, but becomes significant when the flow is normal to the direction of pressing, one result of the increased rate being the loss of ductility.

Before cold forging becomes universally accepted, much more information on it will be required by the designer. It is to be hoped that in the course of the work now being done to discover means of reducing costs and develop correct techniques, his requirements will not be overlooked.

* *The papers presented at this conference are being published in* Sheet Metal Industries.

# ELECTROFORMING A MACH 6 WIND-TUNNEL LINER

*The manufacture recently, in the U.S.A., of an electroformed nickel liner for a Mach 6 nozzle section of a hypersonic tunnel involved the world's largest hand-forged aluminium mandrel, and resulted in the largest nickel liner in the world*

by G. E. SUTILA *

A WIND tunnel which is to be installed in the Aerophysics Laboratory of the Douglas Aircraft Co. Inc. is believed to be the first major hypersonic facility in industry. It will be capable of reaching Mach 10 with a stagnation temperature of 1,200 deg. C. and a pressure of 2,200 p.s.i.

Ideally, the liner for the tunnel should have been machined from a high strength, highly thermal conductive material, but these qualities could not easily be simultaneously achieved due to the inherent geometric and physical limitations. Machining the inner surface of a liner to the highly developed contour needed to create both the velocity and the demanding flow quality would necessitate boring almost 12 ft. deep down to a 3-in. dia., with smaller tolerances and higher finishes than the usual precision work for a piece of this size. The electroforming process, employing a reusable mandrel, allowed the machining to be external, where the contour could be more easily generated and checked. It also permitted the use of nickel, with its high strength and acceptable thermal properties, and duplicated the mandrel surface with very high precision.

The ingot which began the operation was cast at Alcoa's Lafayette works, and was of 2014 alloy, 36½ in. in dia. and 78 in. long. Following casting, the ingot was carefully preheated to develop a thoroughly homogeneous, fine-grained product. This step ensured dimensional stability during machining.

The ingot was hand forged at the Alcoa Cleveland works at approximately 430 deg. C. on an 800-ton capacity hydraulic forging press. Heated flat dies were used. The first working cycle resulted in a thoroughly wrought structure. It was then worked on the press until shaped roughly to the dimensions required by the engineering drawings. In the final step, the forging was laid out and step-sawed to an even closer approximation of the final shape and size.

Following an ultrasonic inspection, the rough forging was sent to Hillcrest Crankshaft & Machine Corp., Titusville, Pa., where the outside diameter was rough machined on a 42-in. Niles finishing lathe. The inside diameter was step-bored on a horizontal boring mill. Although the step boring of this multiple-size hole was exacting, it was accomplished with few unforeseen difficulties, even though the forging was the largest aluminium part ever machined at Hillcrest.

The piece was then returned to Alcoa for a thermal treatment consisting of solution heat treatment and artificial ageing. It was brought to 500 deg. C. and held until all hardening constituents were in solution, then quenched rapidly. As is well known, this processing dissolves the alloying agents and disperses them uniformly in the matrix. Artificial ageing at 180 deg. C. for 10 hr. was employed to obtain the best combination of properties for 2014-T6.

The foregoing sequence and choice of alloy had been decided after consideration of the requirements of the finished mandrel. Most important, the dimensional stability of the mandrel had to be maintained before and especially after the finished machining process. The specifications for the dimensions were so severe that no creep or warpage from residual stress could be tolerated, and as a result diametral symmetry in forging, in heat treatment and in shape were sought. Hence the forging was hardened only after the rough machining and boring.

After thermal treatment the part was ultrasonically inspected once more, then carefully packed and shipped to the Torrance facility of the Douglas El Segundo Division. There, on a Sidney tracer lathe, the mandrel was machined to its engineered dimensions of 12 ft. long, 24 in. maximum dia. and 3 in. minimum dia., and contoured to a high-order mathematical equation.

First, the rough machined piece was finished in the venturi, or throat, in such a manner that the two parts of the mandrel could be separated and withdrawn after the nickel electroforming. This joint in the mandrel was of the most critical importance. The mating surfaces required micro-finishing and matching with absolute cleanliness, so that when drawn together and finish machined, no visual detection of the joint could be perceived. Any infinitesimal opening at the joint would interrupt the electroplating at that point.

The joining of the two parts, forming the throat, was accomplished by running a stainless-steel bolt through the smaller part and threading it tightly into a stainless-steel insert placed in the larger. Three dowel pins through both parts locked the mandrel parts against rotation.

Twenty-nine uninterrupted machining hours were consumed on the finish cut using somewhat over one-thousandth of an inch lead per revolution at 61 r.p.m. and 8½ thousandths depth. Total machining time at Douglas from the rough required three weeks on the Sidney. The final finish after slight hand polishing was 16 micro-inches or better at the throat area, and 32 micro-inches or better on the balance of the mandrel. Radius tolerance was 0·001 in. at each of the 1,440 measuring stations.

The template for the mandrel was hand finished on a surface table by personnel who were skilled in the precision fabrication of wind-tunnel models. Two pieces of 1-in.-thick aluminium plate, mechanically spliced at a prestressed joint, made up the template. The contoured surface was prepared with a coating of molybdenum disulphide to minimise wear and galling with the lathe follower.

Bone Engineering Corp., of Glendale, California, electroformed the liner and assembled the attachment flanges and heat exchange system. The latter is composed of a longi-

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tudinal copper tubing system that circulates cooling water under pressure.

The size of the liner dictated a special vertical installation that incorporated an agitating mechanism to continually move the mandrel during the entire plating cycle. The plating tank and its adjoining pretreatment tank were set 17 ft. below flow level. Nickel anodes were suspended from a circular bus-bar along the periphery of the mandrel during the forming cycle while it was immersed in an appropriate electrolyte.

Prior to immersion, the mandrel ends were sealed by attaching a gasket to each end, and were held in place by stainless-steel caps. These were secured to the mandrel ends with stainless-steel bolts threaded into stainless-steel inserts similar to that used at the throat.

The mandrel was then put through a pre-treatment cycle, which included a proprietary etch that cleaned and prepared the aluminium surface for plating and provided for easy separation of the liner upon completion.

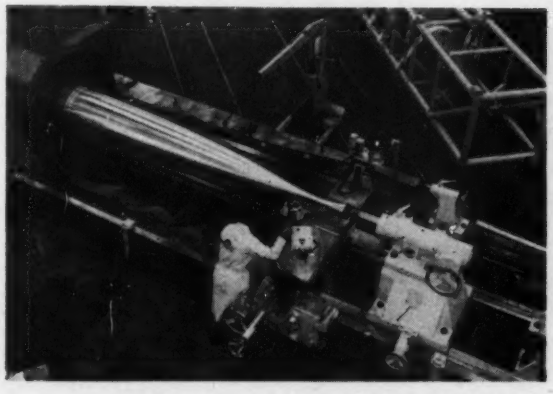
The electroforming of the aluminium part required a high order of quality control to ensure that the electroformed nickel had constant properties. This quality control required daily analysis of the solution during the entire 24 hr. a day, seven days a week, six-week-long minimum cycle. It was preferable that this process should be continuous to avoid an adverse lamination that might have occurred if the operation was stopped.

All operating conditions were controlled within close limits, and a daily check was made of the physical properties of the deposited metal. This was done by testing sample specimens of the nickel deposit that is formed simultaneously with the mandrel. Each daily test checked the ultimate tensile strength, yield strength, elongation, hardness, residual stress and purity of the metal. Not only were these daily tests made at room temperature, but also at the elevated temperatures at which the liner will operate. A high degree of purity was maintained in the electroforming bath by continuously circulating it through a filtration system.

After the nickel wall was built up to more than $\frac{1}{4}$ in. thickness, the mandrel-liner assembly was stress relieved and then returned to the original Sidney tracer lathe at Douglas for a clean-up of the external surface, and for cutting of the buttress threads for the attachment into the wind-tunnel circuit.

Final operations were carried out at Bone, the first of these being the separation of the mandrel from the nickel liner. This was accomplished by reducing the mandrel-liner assembly to a uniform sub-zero temperature. The difference in thermal contraction caused the mandrel to separate from the liner.

Step saw marks on the forged billet.



The mandrel being machined on a Sidney tracer lathe.

This nozzle liner, when installed in the Douglas Aerophysics Laboratory, will be used to generate wind speeds equivalent to 4,500 m.p.h. Similar liners for Mach 8 and Mach 10 are to be made; these will generally follow these same manufacturing steps, except for the addition of a machined beryllium-copper throat.

# ABRASION RESISTANCE OF COATINGS

A NUMBER of improvements have been made by the National Bureau of Standards to their abrasive jet method for measuring the abrasion resistance of protective coatings. The changes have not altered the basic manner of operation, but have significantly increased the speed, ease and precision of the measurements.

In the basic method, pressurised gas propels an abrasive powder from a vibrating storage chamber through a nozzle on to the test specimen, abrasive flow, pressure, distance and angle being closely controlled. Abrasion resistance is measured by the time required to abrade through the coating, and is expressed in terms of a unit thickness. The first show of bare substrate is the end point, and is clearly detected by an abrupt change in colour or gloss.

The equipment allows the economical use of continually fresh abrasive, as well as a large number of repeat tests on a single specimen. Thus the use of a reference panel for calibration and standardisation purposes is feasible, and has become an important part of the improved procedure. The coefficient of variation for measurements on the reference panel is less than 2 per cent.

Close control of the amplitude of vibration is necessary to ensure a uniform flow of abrasive and a constant rate of abrasion. Undesirable turbulence, and interference effects, in the abrasive storage chamber have been minimised by redesigning the chamber so that the abrasive particles sift into and are propelled along a straight tube instead of through a circular chamber. Use of a more free-flowing abrasive (aluminium oxide) than was formerly employed has also improved the uniformity of operation. New devices for setting and adjusting nozzle-to-coating distance to within 0·002 in. have been added.

Studies have shown that the method is not limited to the organic coating materials for which it was originally designed. It is also applicable to ceramic, porcelain and anodic coatings, as well as films and tapes when attached to a rigid substrate. Sheet metal of aluminium, brass or steel may also be tested; their rates of abrasion are of the same order of magnitude as those of the more resistant types of organic coatings.

# NEW IDEAS IN DESIGN

*Outstanding products in current manufacture*

## Equal Tooth Loading for Planetary Gears

IN its simplest form the planetary gear drive consists of the sun gear, the ring gear and one planetary gear journalled to the main bearing support. When it is necessary to increase the transfer capacity of such a drive, two, three or more planetary gears must be employed. To ensure that the increased load is shared equally by all the gear teeth, without elastic deformation taking place, can be difficult. Either the gears must all be cut to extreme limits of accuracy, or the planetary gears must be fitted with intermediate bushings of elastic material. A third alternative is to use the Krupp-Stockicht system, in which the sun and ring gears are located by the engagement of the gear teeth of the three planetary gears themselves and have no mounting of their own. The sun and ring gears in this arrangement must be connected to the further parts of the drive by a flexible coupling. This is only possible, in most applications, at great expense.

Ingenious alternatives to the above solutions have been provided by Simmering Graz Pauker A.G., of Vienna. In the version which employs two planetary gears (Fig. 1), these are mounted on eccentric pins on the planet carrier which are linked together by toothed levers so that the rotation of one eccentric produces an equal but opposite rotation of the other. This results in a state of equilibrium of force distribution in the gear teeth involved.

The forces exerted on the toothed segments are small (see Fig. 4), owing to the large lever action. If, for example, the lever ratio used is

$$a : e = 150 : 5 = 30,$$

then it follows that with an axial loading of $2P$ of the planetary gears ($P$ is the tooth pressure in drive) the force $Z$ on the lever segments is

$$2Pe = aZ, \text{ or}$$

$$Z = 2P\frac{a}{e} = \frac{P}{15}$$

The toothed segments can therefore be rather small—$\frac{1}{15}$ of the sun pinion—and take up only a small space.

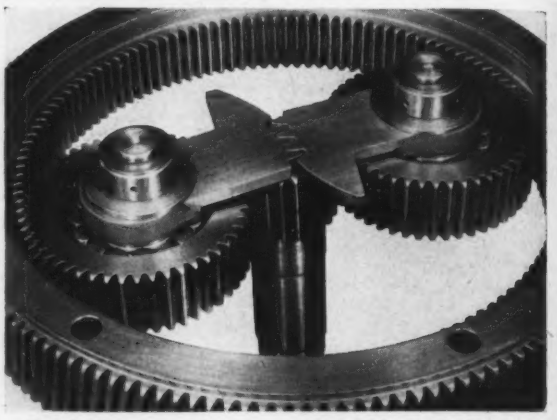


Fig. 1. Two-gear planetary system with toothed load balancing levers.

If the eccentric pins are held in anti-friction bearings in the carrier, the frictional effect is so small that there can be said to be practically precise load distribution, and pure paired forces act on the sun and ring gears, so that, for example, the sun gear can be provided with a floating bearing for heavy loads.

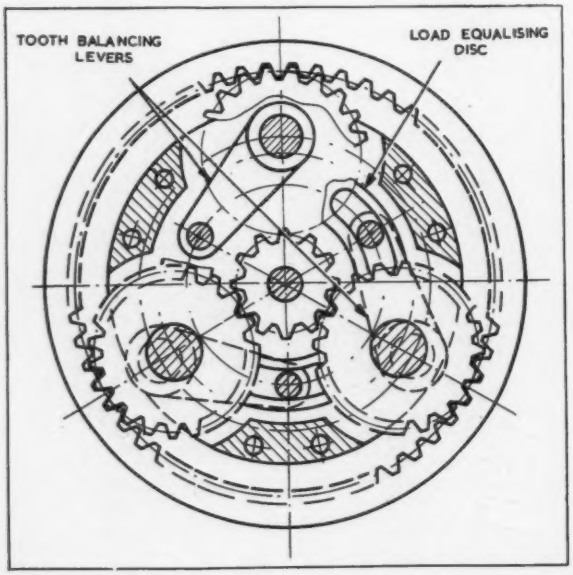
If it is assumed that for a pin diameter of 40 mm. the eccentricity is $e = 5$ mm., then with the designations of Fig. 4 the frictionless moment of rotation of the eccentric

$$M_O = 2P \cdot 0{\cdot}5 \text{ mm.} = 1 \cdot P \text{ cm. kg.},$$

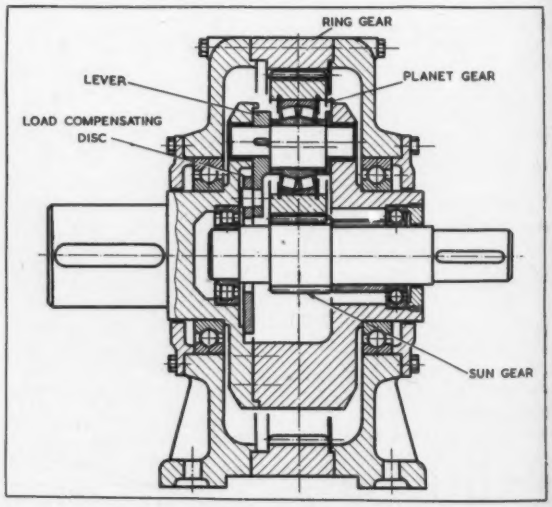
and the frictional moment of an assumed maximum roller bearing frictional number of $\mu = 0{\cdot}005$ is

$$M_R = 0{\cdot}005 \cdot 2P \cdot 2 \text{ cm.} = 0{\cdot}02 \cdot P \text{ cm. kg.},$$

which is 2 per cent of the frictionless moment. In other words, this is a load equalisation of 98 per cent completely independent of manufacturing inaccuracies. In addition, despite the fact that the planetary gears are eccentrically mounted, the deviation from the zero position of the balanc-




Figs. 2 and 3. Load balancing arrangement for a three-gear planetary system.



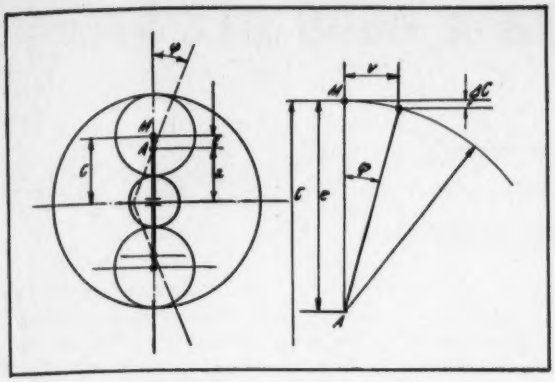


Fig. 4. Geometry of the two-gear arrangement.

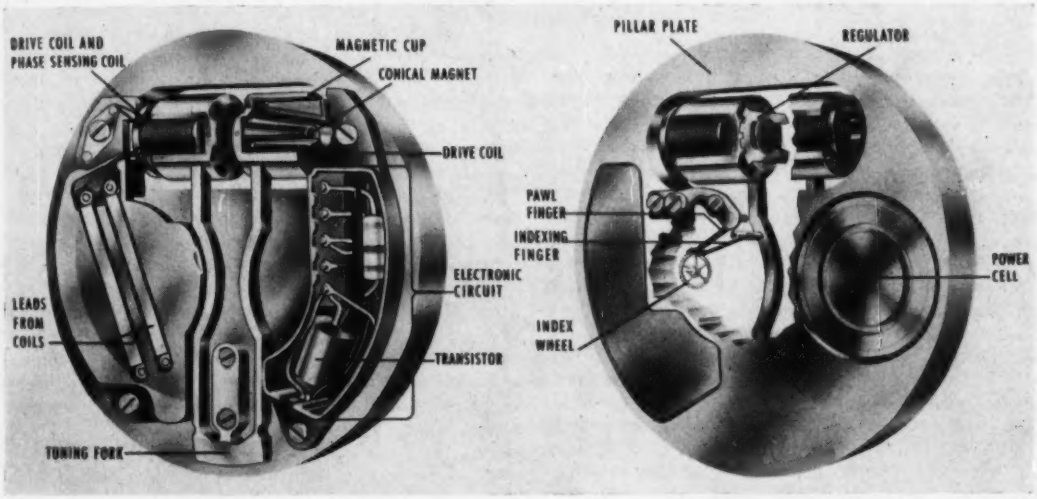
ing levers, even if a lever displacement of 2 mm. is assumed, is only 25 $\mu$ and can be neglected.

Another load-balancing arrangement for three-gear planetary systems is also shown. In this the load-balancing device consists of a disc, having three equi-spaced arcuate slots, which serves to distribute load variations in the planetary gears via three levers. The levers are fixed to the three eccentric planet carriers and each carries a peg which engages one of the slots in the load-equalising disc.

The disc is provided with a hole at its centre which is considerably larger than the sun gear. This hole enables the disc to move laterally to the sun gear axis by a sufficient amount to compensate for any unequal tooth loading that may occur.

The manufacturers claim that with these devices it is possible to ensure good meshing without recourse to excessive degrees of accuracy in the methods of gear manufacture adopted.

## The Electronic Watch, a Breakthrough in Horology




THE heart of the Bulova Watch Co.'s Accutron watch is an inch-long tuning fork, tuned to vibrate at 360 c/s. Attached to one tine of the fork is a jewel-tipped index spring which engages on the ratchet teeth of an index wheel, thereby advancing the wheel one tooth for every vibration of the fork. From then on the motion is transferred from the index wheel, via the gear train, to the hands. On the return vibration of the fork, the index wheel is held in position by a second jewel-tipped spring, acting as a pawl, mounted on the pillar plate. The scale on which the plate is made is illustrated by the fact that about 8,000 index and pawl jewels would be needed to cover a sixpence. The index wheel is only 0·05 in. in diameter, and only half a hairsbreadth thick. The rim is machined into 300 teeth, the gap between the teeth being only 0·001 in. The index wheel is made from special copper-beryllium alloy. Reliance is not placed on the amplitude of vibration of the fork. The design of the indexing mechanism takes into account the forces exerted by the index and pawl springs, which also provide the kind of back "draw" provided by the banking pin to the pallet fork on a conventional watch.

The electrical side of the movement consists of a power cell, a transistorised electronic circuit, and an electromagnetic assembly. A cup-like piece of magnetic iron extends outwards from both of the tuning fork tines, each cup enclosing a conically shaped magnet. A strong magnetic field lies between each cup and magnet. Stationary coils extend into the magnetic field, the magnet assemblies moving with each vibration of the fork. Energising the coils causes alternate attraction or repulsion of the magnet and cup assembly, and conversely as the magnet and cups move, an alternating current is induced in the coil. Thus the function of the coils is to drive the fork by converting electrical into magnetic energy which controls the amplitude of the fork by sensing the alternate voltage induced at each cycle, thus controlling the instants during the cycle when the driving pulse is to be delivered.

The electronic on-off switching circuit consists of two interrelated sections, each connected to the 1·3-V. mercury power cell and a germanium transistor. The transistor acts as a relay for delivering a pulse for each cycle of the fork. The coil side of the circuit has already been explained; the other half consists of a capacitor with an associated resistor as well as the phase-sensing coil.

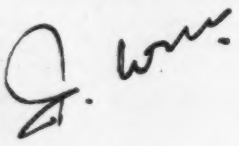
In operation the alternating current induced in the phase-sensing coil is added to the power cell voltage to charge the capacitor. The current flows through the base circuit of the transistor which acts as a diode or rectifier. The resistor causes the capacitor to leak, so that it is recharged once during each cycle by the peaks of alternating voltage induced in the phase-sensing coil, the pulses caused giving rise to momentary conductivity in the base circuit, thus causing the relay to close for an instant.

This watch does not tick—it hums!

# WHAT MAKES A GOOD DESIGNER?

*The question "What characteristics do you look for when selecting design staff?" was posed to four well-known personalities in various branches of the engineering industry—here are their replies*

**J. WYER**, director and general manager of Aston Martin Lagonda Ltd.



THE question "What characteristics do you look for in selecting design staff" should be a simple one to answer, or so it would appear at first sight. In fact, it has proved surprisingly difficult.

Probably this is because of the rather special conditions under which we work. At Aston Martin Lagonda we have as our target the production of a car which will compare not unfavourably with the best in the world. Because of our inevitably small volume, we have to work with what can only be regarded, in relation to the magnitude of the project, as an extremely small engineering team. Therefore, although we demand high standards we cannot afford specialists. A designer may—and almost certainly will—be expected to accept responsibility for several aspects of the finished product. A development engineer cannot hope to shut himself away for long periods with one problem, eventually producing an excellent and detailed report long after the need has been forgotten. He will be expected to know something about tyres one day and lubricating oils the next. With these desiderata in mind, we can now start to consider the qualities we look for. I would put them in the following order:

1. A sound engineering background, broad based rather than highly specialised.

2. Theoretical, as well as practical, knowledge of the problems involved. Increasingly, we must tend to consider only graduates for the key engineering positions.

3. Interest in the product and its development. If the first two characteristics have been somewhat obvious, the third is perhaps even more important. Due to the diversity of the problems which the designer may be asked to undertake, it is essential that he can see the product as a whole and retain an individual interest in its perfection.

4. Breadth of vision combined with a logical analytical approach to detail. This follows on from 3. When the demand arises the designer must be able to focus his energies and abilities on the solution of one particular problem without losing sight of the overall picture.

5. Knowledge of manufacturing processes. This is very vital. The designers will be called upon to give close liaison and support to the planning engineer, and must have knowledge of the potential of the available plant and tooling.

6. Ability to work in a team. I have put this last because it is the characteristic which welds all the others into a useful entity.

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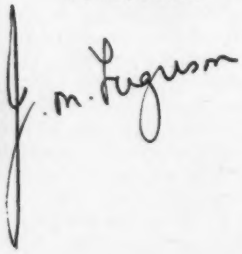
**J. M. FERGUSON**, chief engineer of The English Electric Co. Ltd., Stafford.



THERE is not yet adequate appreciation or recognition of the responsibility of design. Inevitably, as the meticulous calculation and cherished drawings of the designer emerge through a plant and take shape as finished products, inadequacies and faults become plain for all to see. Does a product function incorrectly? The designer has been in error. Is a product competitive? The designer has lacked originality or adhered to tradition too strongly or has played too safe. Has the designer got the flair for form and shape and clean appearance, or does his work bear the stamp of ugliness?

Can design be taught? The basis of design may be taught, but this does not create a designer. A good designer may certainly be recognised by his work, and equally a bad designer, but this recognition occurs too late to take effective action. A good designer must have intelligence, enthusiasm, integrity and humility. In the past he has emerged from a works background, steeped with a knowledge of how things are fashioned and put together. Usually now he must have an academic background, appreciate the results of research, be able to use modern design tools such as digital computers, have good knowledge of methods of tooling and manufacture, be aware of new materials and be imbued with a strong sense of the economic use of materials. Where a designer acquires or should be taught all these skills is one of the most difficult problems in this field today.

In selecting design staff, assuming an adequate academic standard, I would look for enthusiasm to do something and willingness to co-operate with other people. Experience in development work is valuable as it widens the outlook, and knowledge of manufacturing, tooling, works study, planning and all manufacturing techniques can be most useful; but, above all, I would look for a willingness to accept the full responsibility involved in design, and a strong sense of pride in the creation of something worth while.

J. TINDALE, assistant joint general manager of Elliott Brothers (London) Ltd.

THE term "designer" covers a wide field, ranging from the functional to the æsthetic. The interpretation I wish to review is that of the engineering designer, whose criterion for perfection is good functional performance.

A designer must have the knowledge and experience of how the things which he is to design are to be made. It would be useless to design an article which, although it will meet the functional requirements, cannot be manufactured or which will require such means as to render its cost prohibitive. A designer, therefore, must be one who appreciates limitations of production engineering as applied to that which he is to design.

He must be conversant with the material characteristics of the media which he wishes to use. There is beauty in so-called functional design only in so much as the lines suggest the optimum use of the material under stress. The term "stress" is used here in the broad sense, since strength and rigidity are as important to the functional use of a piece of chinaware as they are in a structure built with metal or concrete.

Recognition for the environmental suitability of the material must be acquired by the designer. He must be capable of absorbing the results of research engineering not only in the discovery and application of new materials but also in new methods of construction, manufacturing processes, and new methods of calculating the suitability of a design for the solution of the set problem.

The designer must have a clear analytical mind devoid of personal bias, he must be capable of assessing the merits of his design on calculated performance, and have a strength of character to discard his own design in favour of others.

A designer should be an artist, capable of inwardly seeing the finished design whatever his particular calling. An artist is capable of sketching on a board that which his mind projects on to it. A successful designer must be capable instinctively of producing a design which appears to be right. Subsequent checking of the design by mathematical calculation should result in very little amendment to his original concept. He can learn to do this by memorising the characteristics of the materials, but initially he must have encouraged his basic quality for creating or inventing things. This is best done by being humble in the knowledge of inspired thinking.

The new age designer might approach his work in a somewhat different light, in view of the fact that the methods of production are different and the approach to the correct solution is so complex as to be only capable of solution by an automatic computer. Yet basically all those qualities of the present-age designer would still be required with his knowledge, intelligence, perception, patience and integrity; but above all with inspiration and the ability to change an idea into a practical solution.

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F. H. POLLICUTT, technical director of Hunting Aircraft Ltd.

THE modern trend of increasing complexity and specialisation is well exemplified in the aircraft industry. Aircraft of today require too many different engineering skills to be the brain-child of one man, and the design staff of an aircraft company is more and more composed of specialists in aerodynamics, structures, materials, mechanisms, electrics, hydraulics, etc., each making his own contribution to the whole. Increasingly, too, in many of these fields the technician and the draughtsman are different men, with an ever-increasing ratio of technicians to draughtsmen.

It follows that there can be no single standard of suitability for individuals in an organisation of this sort. Every specialist division, and almost every post in each division, has its own requirements, both in technical qualifications and in personal characteristics. For example, the bold imagination and originality needed of a project designer would be wasted, and could even be a handicap, in the equally important but more humdrum task of routine modification. An aircraft design staff is not a regiment of like individuals, but a team of exceedingly diverse ones, and the selector's primary consideration is to maintain a reasonable balance—between age and youth, between the various technical skills required, between academic qualifications and hard-won practical knowledge, and between the variety of personal attributes that make up humanity.

The last is the most difficult, but if the selector is successful his individual specialists will achieve more in combination than on their own. The design team will acquire a corporate entity of its own; it will pull hard—and pull together.

From this springs the only golden rule in staff selection. A man may have all the technical qualifications in the world, but he will be a liability rather than an asset unless he possesses the two non-technical qualities of enthusiasm for the job and willingness to co-operate with others. Nothing worth while was ever accomplished without enthusiasm, and nothing nowadays can be accomplished on one's own.

The selector's job is more of an art than a science. This is even more the case when it comes to promotions, and planning the careers of younger men. The man who is first rate in his existing job is not necessarily suited to hold the post next above it, and there is a world of difference between the embyro chief designer and the conscientious plodder who can surpass him in limited fields.

The man at or near the top of a modern design organisation—of any organisation if it comes to that—is not relying on his own personal skills in the business in hand, but on getting the best out of others. To be a patient, sympathetic co-ordinator is not enough; he must have a wide outlook to see beyond the end of his present projects and to detect weakness and false reasoning in technical fields other than his own. Design staff selection is an art, and an art that is never finished.

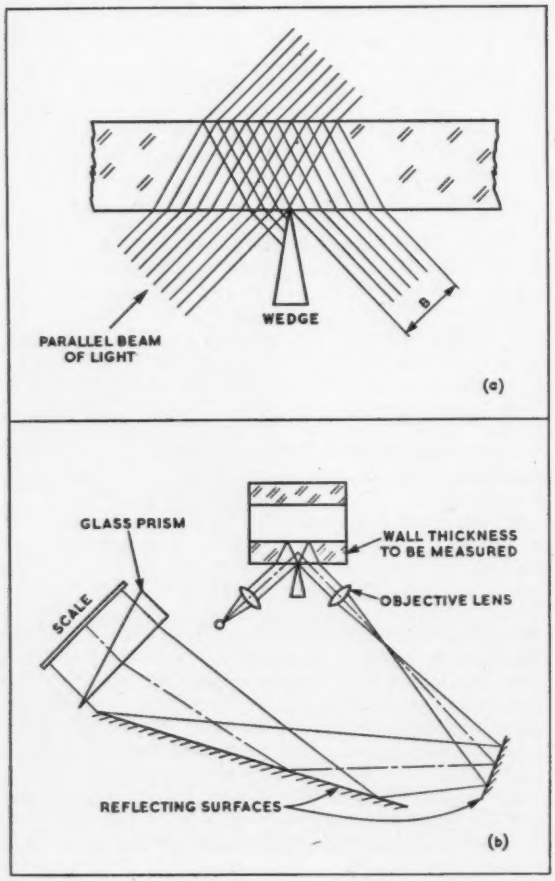
# OVERSEAS NEWSLETTER

*A monthly digest of reports from our foreign correspondents of other countries' current achievements in research and development work*

### Measuring the Wall Thickness of Glass Bulbs

The wall thickness, and in particular the surface uniformity, of a glass bulb is of great importance for the life of incandescent lamps, thermionic valves and discharge lamps. Its measurement without destruction of the bulb has always posed a problem, but now VEB Feinmess-Dresden (German Democratic Republic) have developed an instrument for conveniently measuring the wall thickness of glass bulbs to an accuracy of 0·1 mm.

The principal of measurement is shown at (a) in the accompanying illustration. A wedge is applied to the bulb wall, and a beam of parallel light is thrown upon it from one side of the wedge. Due to double refraction and partial reflection by the glass wall, a beam of parallel light issues from the other side of the wedge. The width, *B*, of this beam depends on the thickness of the glass. Thus the direct measurement of thickness is replaced by reading off the width of the reflected beam on a ground-glass screen provided with a suitable scale. A diagram of the instrument is shown at (b).




However, the width *B* depends also on the incidence angle of the beam, and on the index of refraction of the particular glass. The instrument is therefore designed so as to give a constant angle of incidence. The values of the refraction index can be corrected by pivoting a glass prism by means of a knob on the side of the apparatus; this knob is provided with a scale including the entire range of refraction indexes of the various types of glass used for bulb manufacture. The objective lens is interchangeable, which makes it possible to use the instrument for two measuring ranges, viz. from 0 to 6 mm., and from 0 to 12 mm. of wall thickness respectively. The scale readings in the first case are 0·1 mm. with ±0·05 mm. maximum deviation, and in the second case 0·2 mm. with a deviation limit of ±0·1 mm.

### Economical Carburetters

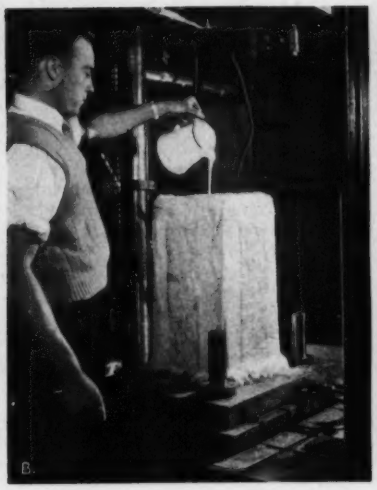
Internal combustion engines with a controlled preliminary mixture of petrol and air usually work with a carburation mixture richness of between 0·95 and 1·2. By using less rich mixtures, it is possible to increase the motor output and reduce the CO content of the exhaust gas, but the use of a lean mixture with controlled flow brings with it two main problems. First, it is difficult to ignite the mixture, and, second, the subsequent rate of combustion is insufficient, and results in loss of power. Various ways of solving these problems have been suggested.

One new approach has been the subject of recent experiments at the Institut Français du Petrole. This method consists of producing, in an unmodified combustion chamber, a mixture of heterogeneous richness by introducing the carburated mixture in two streams of very different richness. The resulting heterogeneity makes possible a localised enrichment of the mixture near the sparking plug, thus assuring correct combustion of the overall lean mixture. By changing instantaneously from a lean to a rich mixture without interrupting motor operation, it is possible to control the motor power over a wide range solely by means of the mixture richness, while maintaining motor performance.

Tests on this process have shown that correct combustion can be obtained down to a minimum richness of 0·5. By applying this to car engines, the petrol consumption can be reduced by about 10 per cent. Moreover, CO may be eliminated from the exhaust gas in all operational conditions where maximum power is not required.

### Friction Welding

A new and efficient technique for welding metals by friction has been evolved by the Electrowelding Research Institute of the U.S.S.R., who have recently developed two special machines, the MST-1 and MST-2, for butt welding by friction. Both machines are designed for welding workpieces for cutting tools, and differ from one another only in the way they grip the part. In principle, friction welding can be carried out on almost every type of metal-working machine, but the swift and heavy wear on unsuitable machines must be taken into account.



# POLYESTER-GLASS UNIT USED IN NEW WASHING MACHINE

TOUGH, non-rusting polyester-glass is being used for inner liner of the spin-dryer section of the new A.E.I.-Hotpoint Supermatic washing machine. A remarkable feature of this liner, made by Thermo Plastics Ltd., of Dunstable, is the very high degree of moulding accuracy required by the makers of the washing machine. The liner had to be made with a draw of over 21 in., and an allowance of only 1° 21 min. on the sides.

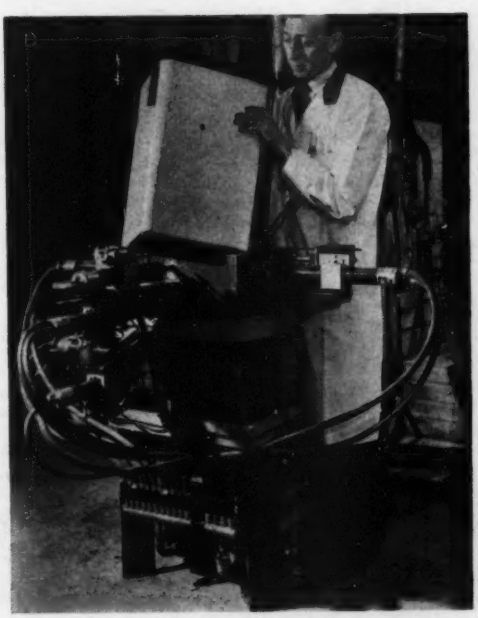
Cellobond polyester resin (made by British Resin Products Ltd.), reinforced with glass fibre, has proved particularly suitable for this use because of its high strength/weight ratio, and its freedom from fatigue failures. Also, it has a low expansion factor over the temperature range to which it is subjected in this application, and is unaffected by water, chemicals or galvanic action.

Due to the desired shape of the moulding, the glass fibres are pre-formed on the American L.G. Brenner pre-former (see illustration *A*). This consists of a perforated forming screen rotating inside a closed chamber. Glass fibre strands are fed into the chamber from reels. As they enter the chamber, they are chopped into short lengths and drawn on to the screen by suction. When the required thickness of glass has been built up, the chamber is opened, and the pre-form is sprayed with a resin emulsion. It is then cured in an oven. The cured pre-form is placed on the male mould of a 100-ton Daniels press. Matched metal moulds are employed, resulting in a high rate of production of perfectly finished dimensionally accurate mouldings.

A predetermined charge of Cellobond polyester resin is poured on top of the pre-form in the press (see *B*). The press is then closed, forcing the resin so that it is dispersed uniformly throughout the pre-form, while heat is being applied.

After a few minutes the press is opened again, and the cured moulding is removed (as in *C*). A recent development (not shown in the photographs) is that a polyethylene spout is now moulded integrally, thus increasing the overall depth by 1¼ in.

After the moulding has cooled, it is placed in a special multi-drilling jig (see *D*), which automatically drills sixteen holes of varying diameters simultaneously, at predetermined points in the sides and base. The jig was specially designed and built by Thermo Plastics Ltd. for this moulding.



# New Books

**Basic Graphical Kinematics.** *By Harold B. Kepler.* (*McGraw-Hill—46s. 6d.*)

This volume serves as a useful introduction to a branch of mechanics which to many engineers remains a mystery, and which at some time in the future may have to be rapidly solved. If the time can be spared now, study of this text will prove rewarding, and should the requirement to produce a practical design arise, reference to the many fully detailed problems is almost sure to provide the correct method of approach.

The author does not claim to have produced any entirely original methods, but he has drawn from many acknowledged sources in an effort to produce a compact work covering the essential fundamental data. Excepting gears and cams, which lend themselves to synthesis techniques, only existing mechanisms are dealt with, this on the assumption that a good knowledge of established designs is the basis of original thought.

Beginning with vectors and vector equations, and then on through basic motion concepts, displacements and drawing techniques, the author proceeds step by step to explore the many problems involved in setting out the various types of mechanism. An explanation of the Coriolis Law is given, together with the equivalent linkage concept which serves to simplify many problems without the introduction of the former.

All sections are profusely illustrated with line diagrams and many fully worked examples. Additionally, photographs are used, where necessary, in order to illustrate actual examples of the mechanisms under discussion. Sufficient problems are set at the end of each chapter to ensure that the reader has some variety in the method of approach.

One is left with the impression that this handy volume may serve equally well as a student's text or as a reference for the practical engineer who requires the occasional refresher to stimulate new thought.

*R. B. Selwyn*

**Motor Boat and Yachting Manual.** *Sixteenth edition.* (*Temple Press—15s.*)

While this book is basically indispensable to owners and amateur builders of boats of all types, one suspects that it is also an invaluable reference book to the professional marine architect. For this latter reason it is recommended to land-based designers, as it contains many sound fundamental design notes which could be applicable to other forms of engineering. Lists of petrol and oil engines suitable for boats of all sizes are given, together with their power, weight and current prices. To sum up, the book is invaluable to those connected with marine activities, useful to designers in other fields, and of absorbing interest irrespective of the readers' age or occupation.

**Polyester Resins.** *By J. Lawrence.* (*Reinhold; Chapman & Hall—46s.*)

As with the other books in this series, the theme is guidance in application. This particular one is of interest because of the widespread use of polyester resins in reinforced plastics. The first part of the book deals with the history, chemistry and properties of the resins with subsequent chapters on their manufacture and curing by various catalysts. Chapters 8 to 11 deal with moulding and laminating processes, and various applications. The appendices form a substantial part of the useful information, and include a tabulated guide to commercial resins; while these are of American origin, the details are sufficient to enable a British equivalent to be suggested. A "trouble-shooting" guide is a useful addition.

**Glass Fibre Reinforced Plastics.** *Edited by A. Dani.* (*George Newnes Ltd.—50s.*)

This book is intended to provide the reader with practical as well as theoretical information on the production of glass-reinforced plastics components. The various types of glass fibre and resin are dealt with at length. These chapters are followed by a description of the hand lay-up method, including details of equipment and the various types of rollers used. Methods of moulding for various shapes and forms are discussed, and subsequent chapters deal with low-pressure mouldings, high-pressure mouldings, jigs, tools and finishing operations. The considerable attention that has been paid to the general form and layout of this book makes it easy for the reader to refer to any particular aspect.

**Applied Engineering Mechanics.** *By Alfred Jensen and Harry H. Chenoweth.* (*McGraw-Hill—50s. 6d.*)

Divided into two complementary parts, statics and dynamics, this volume provides a basic text for those students intending to pursue the higher mechanical engineering courses leading to degrees or membership of the professional institutions.

As might be expected, the method of presentation is geared closely to a background of an American High School education. In none of the examples given is a knowledge of calculus assumed. In fact, every example may be completed with recourse to fundamental mathematics only. However, in the well-laid-out appendices will be found the calculus approach to computing centroids of areas and moments of inertia of plane areas and of solid bodies. In addition, a short discussion on variable acceleration and the derivation of the laws of motion diagrams is included.

Both sections begin with basic principles and gradually work through all the various subdivisions of the title subject. Chapters, subsections and paragraphs are numbered for easy reference, as are the problems and "Review Questions" which follow them.

The many problems presented towards the end of each chapter are carefully graded so that the student proceeds from the elementary to the more difficult by easy stages, gradually combining the individual elements of his knowledge to solve those of the most advanced nature. Each chapter concludes with a useful summary of the important points and formulæ covered in that part of the text.

Great emphasis is placed on graphical solution, in the belief that the student is more able to visualise the force analysis, thus finding it easier to proceed with the corresponding analytical method. In the latter, students are encouraged to produce the complete "Free Body Diagram" as the solution progresses. Finally, arithmetical summations are proposed which provide a quick check on the correctness of the answer obtained.

Generally it can be said that much thought and preparation has gone into the production of this work, which could prove a handy source of reference for the student engineer.

*R. B. Selwyn*

## OTHER BOOKS RECEIVED

**Drilling Cast Iron.** (*Production Engineering Research Association—7s. 6d.*)

Research report giving recommendations on drills, including their grinding, life, and power required.

**Runnerless Moulding.** *By E. Moslo.* (*Reinhold; Chapman & Hall—40s.*)

Theory, design, applications and economics of various injection techniques associated with runnerless moulding for plastics.

**Introduction to Atomic Energy.** *By W. G. Atkinson.* (*Rider; Chapman & Hall—11s.*)

Straightforward presentation of basic nuclear reaction, types of reactors and materials.

**Springs.** (*Flexo Steels Ltd.—4s.*)

Catalogue of compression and tension springs of all sizes. Data includes spring rates, etc.

**BS Handbook No. 4, Pt. 2: 1960.** (*British Standards Institution—40s.*)

Fifteen standards for chains and hooks are reproduced in full, together with a summary of material specifications.

**BS 1500A, Pt. 1: 1960.** (*British Standards Institution—12s. 6d.*)

Extracts from BS 1500, Pt. 1, dealing with the manufacture, workmanship, inspection and testing of fusion welded pressure vessels.

**BS 1579: 1960.** (*British Standards Institution—6s.*)

Revised to take account of the types and sizes of timber connectors now generally available in this country.

**BS 3279: 1960.** (*British Standards Institution—5s.*)

Supersedes the relevant part of BS 954 dealing with "Lac".

**BS 3280: 1960.** (*British Standards Institution—10s.*)

Supersedes the relevant part of BS 954 dealing with "Lac".

# LETTERS TO THE EDITOR

## Information for Engineers

Sir,

Under "Information for Engineers" (p. 28, January), Mr. F. Machon refers to the D.S.I.R. publication *What They Read and Why*, not saying that this is an outline summary of the more complete *The Use of Technical Literature by Industrial Technologists*, by C. Scott and L. T. Wilkins (the Central Office of Information). The former publication relates to technologists in the electrical and electronics industries only. Wider in scope was a survey by the European Productivity Agency, entitled *Technical Information and The Small Firm (European and American Industry)*, published by O.E.E.C. The firms surveyed were in metal manufacture, engineering, electrical manufacture, textiles and food manufacture. Both surveys seem to reach the same general conclusions, chiefly that technologists appeared to think they covered all the literature and knew all that was afoot although they seldom studied their trade periodicals—at least systematically.

The confidence of the technologists rested on quite other sources of information. If a particular problem arose they would consult their colleagues and, outside: (1) suppliers of materials and products; (2) technical consultants; (3) subscription research organisations; (4) public research organisations; and (5) universities. The technical consultants who advised them used: (a) literature; (b) "inside" information; (c) "other firms", i.e. the suppliers above; and (d) lectures and exhibitions.

Rather than a classification of information required by engineers, given as News, Data or Background, it seems to me that what they seek is, first, information giving continuity to an existing background, and, second, information concerning a specific aspect of a problem, to solve one that has arisen. The surveys suggest that for neither category do technologists go to "specialist scanners", whatever they may be. If they exist, why do they have no faith in them? It seems to me that the answer is this: The answers they seek require not specialist scanners but industrial knowledge and experience, knowledge of the history of many branches of technology, commercial information and information in the making, acquired before it is written about. It will be specialist industrial technologists who take the enquirer's problem in hand in the "supplier" firms, and who will draw up a technically assessed recommendation, relate it to the known experience of other customers, and offer to provide further help. If the problem then goes to a consultant, he will add his knowledge from an analysis of the literature and his acquired experience. If the query goes further to a subscription research organisation, it will do so automatically to get some return for the subscription. If very basic, it may go to public research.

If by specialist scanners is meant information officers, then it is clear that they can be just one contact in a search for specific information, and not one best placed to help. One need only consult the advertisements for them: "Graduate in so-and-so (not generally asked to have industrial experience) with library qualification, knowledge of a foreign language useful!" Useful indeed! How does he cover the world literature without fluent reading capacity in at least two or three foreign languages of industry and commerce? And if he is what the advertisement suggests—skilled in indexing and classification of literature—he performs the work a machine should be able to do, did we but classify numerically. But then, that would need skill—and real knowledge of languages—because the titles of many articles very far from represent the essential theme of content.

For the man who wants to keep abreast, many of the index references given may be seen "in the flesh" in most commercial libraries in the larger cities. And the intelligent technologist will also have consulted the librarian of his professional institution, and maybe the editors of the journals covering his field. Generally, services such as Engineering Index will be a year behind, unless the current card issuing system is subscribed to, which for many is too expensive. More useful than an arbitrary list of sources would be to direct attention to a survey of them, such as *Records and Research in Engineering and Industrial Science*, by J. E. Holmstrom (Chapman & Hall). And when it comes to lists of available foreign periodicals, those issued for the asking by firms such as Dawson's, and Collet's, are worth mention.

It may be worth reflecting that in every branch of technology there are acknowledged names requiring a first check, apart from the most recent article not yet proved. Do specialist scanners, I wonder, compile a list of names and the specialisms they are acknowledged authorities in? Some will know what is meant if I mention Bowden & Tabor, Hertz, Earle Buckingham, Timoshenko, Lanchester-Prandtl.

A caution .... Your article leaves the impression that P.E.R.A. will supply photocopies of articles to anyone, but that A.S.L.I.B. only do so to members. In fact, the same restrictions apply to both and, moreover, they are each bound by copyright law—a single copy for exclusive personal use. Again, although some research associations themselves digest the press in abstracts, I have known such an association more than once to compile a report on months of research unaware that the same work had been published abroad some time before. One must assume that the abstracting was not so good, or perhaps the application of it, and the committee directing the work, failed to assemble men sufficiently aware of the subject and foreign work in it, to see that they first had a report on the state of knowledge abroad.

In this country there is no co-ordination in the technological field, of the specialised literature held by each D.S.I.R. grant—supported research association. D.S.I.R. itself has a reference library and translations section, so have some of the associations, but they have no common literature classification scheme and no collective catalogue of holdings. Nor is this literature accessible to the general public or to industry generally, although they pay for a third of it; it is only for subscribing members.

A.S.L.I.B. has published—to its members—a number of papers that cover a good deal of the ground that Mr. Machon does, and more detailed ones on the literature of certain branches of industry. These, too, should be known to the engineer. Mr. C. W. Hanson, of that association has written similarly in *Engineering* (September 16, 1960) under the title "Deciding What to Read to Keep Informed", and from correspondence between him and Mr. Machon it seems that there is a conflict as to how personal to the engineer this business of keeping abreast is. I do not think "specialist scanners" are the answer, unless they themselves embody very wide industrial experience and broad interest in all that goes on in science, and have, in addition, a knowledge of several significant languages.

**W. D. Arnot**
16 Chapel Street,
Nuneaton, Warwicks.

Sir

We should be glad to know the source of your information about *British Chemical Plant* (p. 29, January), as what you have given is wrong in two important respects, i.e.: (a) the publication is issued every two years, not twice a year; and (b) it is neither an abstract nor a summary, but a buyer's guide to chemical plant made by members of the Association.

**J. L. Good**
(Secretary)
British Chemical Plant Manufacturers Association,
14 Suffolk Street,
London, S.W.1.

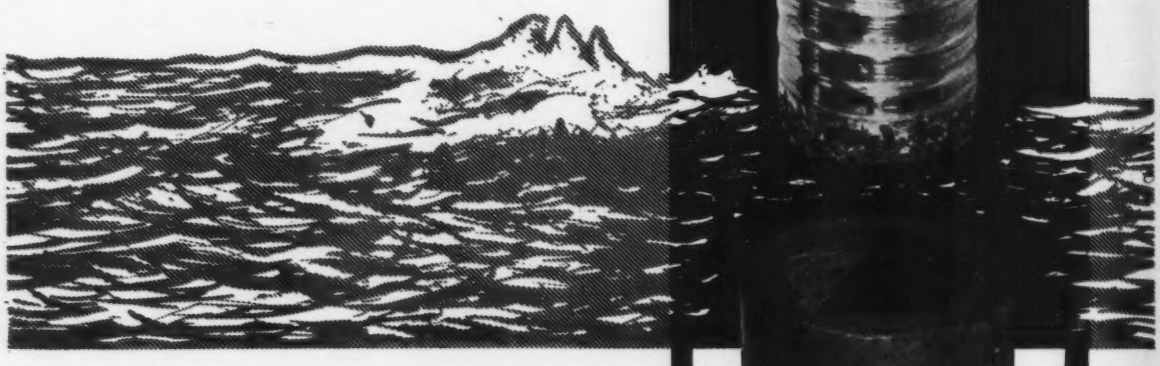
*We understand that the* 1961 *edition of* British Chemical Plant *will be available in the Autumn.*

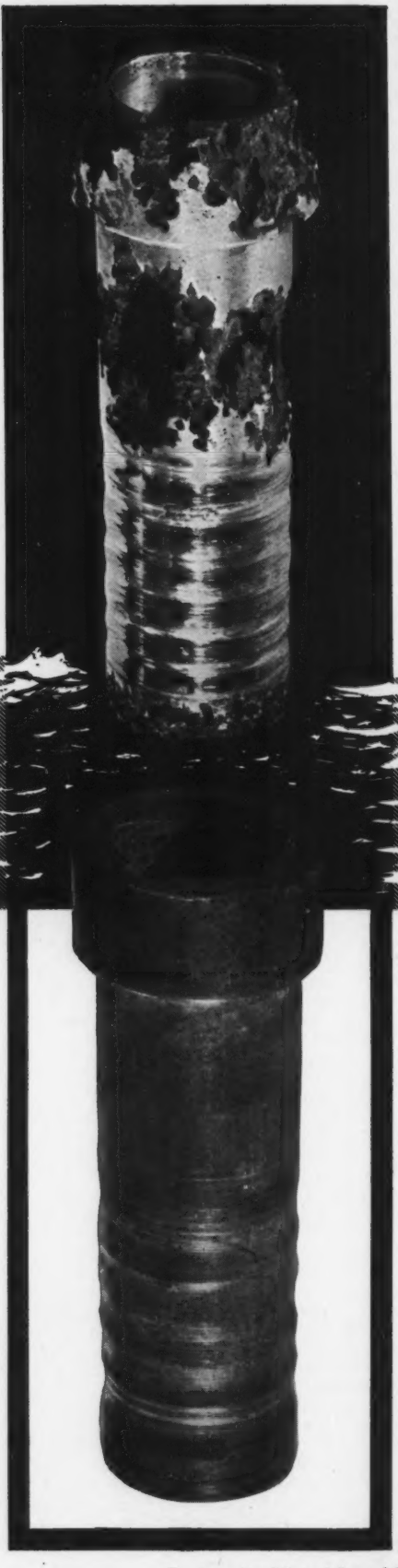
## Railway Modernisation Conference

A conference on railway modernisation is to be held at the Institution of Civil Engineers, in London, on May 3 and 4. Five papers will be presented: "The Engineering Aspects of the Modernisation Plan for British Railways", by R. C. Bond (technical adviser, B.T.C.); "The Contribution of Civil Engineering to the British Railways' Modernisation Plan", by M. G. R. Smith (chief civil engineer, Western Region, British Railways); "The Impact of Mechanical Engineering on the British Railways' Modernisation Plan", by J. F. Harrison (chief mechanical engineer, British Railways' Central Staff); "Electric Traction in the British Railways' Modernisation Plan", by S. B. Warder (chief electrical engineer, British Railways' Central Staff); and "British Railways' Modernisation—Signal Engineering and Telecommunications", by J. F. H. Tyler (chief signal and telecommunications engineer, Southern Region, British Railways).

# PEPPERED WITH SALT

The TUFNOL and stainless steel sleeves illustrated have each given 9 months service rotating at 1465 r.p.m. keyed to the shaft of a tidal river water pump at the C.E.G.B. Stella North Power Station, Lemington-on-Tyne.





The TUFNOL sleeve (bottom illustration) shows no sign of corrosion or mechanical breakdown. Indeed the next pair of TUFNOL sleeves fitted were in use for over 12 months without having to strip the pump for examination. Furthermore, no tightening up on the packing gland was required whereas this had to be done every week with the stainless steel sleeve.

*Why not ask for an engineer to come and talk TUFNOL with you?*

# TUFNOL

(REGD. TRADE MARK)

**TUFNOL LTD · PERRY BARR · BIRMINGHAM 22B**

*Other saltwater applications include ships' propeller shaft bearings, rudder bearings and engine mountings, besides a wide variety of yacht fittings.*

376

# MEDIUM STRENGTH TITANIUM ALLOY (2% Al, 2% Mn—to DTD 5043A)

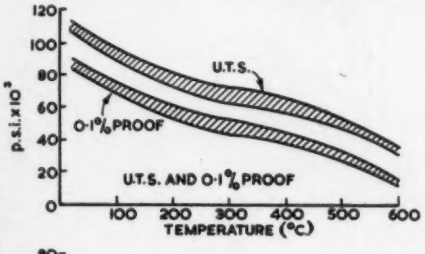
**Engineering Materials and Design**
DATA SHEET No. 54

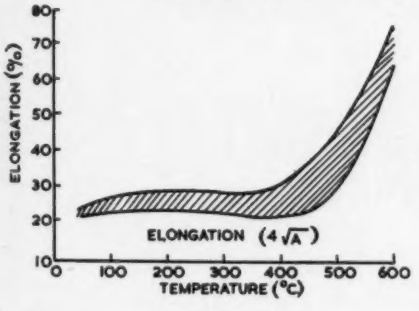
This data sheet describes medium-strength forging stock and bar produced by Imperial Chemical Industries Ltd., Metals Division (314 C), and Jessop-Saville Ltd. (Hylite 30).

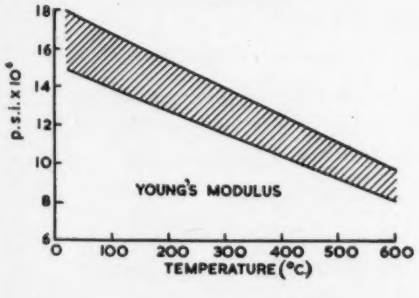
Because of the differences in chemical composition and processing of the material produced by each company, the following curves indicate the bands within which typical values lie. These bands, the result of combining the information made available by each of the companies concerned, do not indicate the spread of any one manufacturer's material.

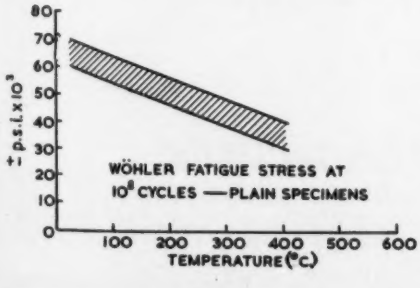
It should be emphasised that the curves relate to "typical" properties only, and should not be interpreted as representing maximum or minimum values. They should not be used without reference to DTD or manufacturer's specifications.

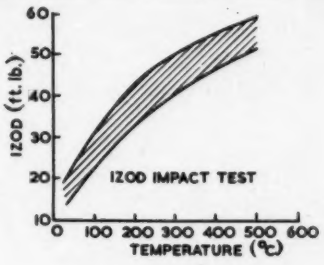
Density at 20 deg. C. —0·16 lb./in.³
Forging temperature (max.)—870-875 deg. C.
Subsequent heat treatment—see relevant manufacturer's instructions.

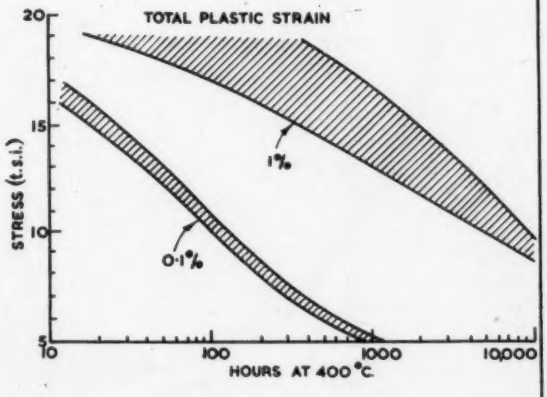


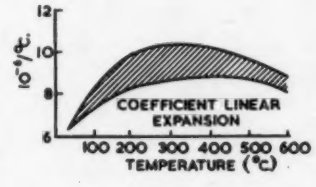



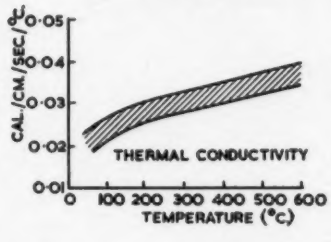



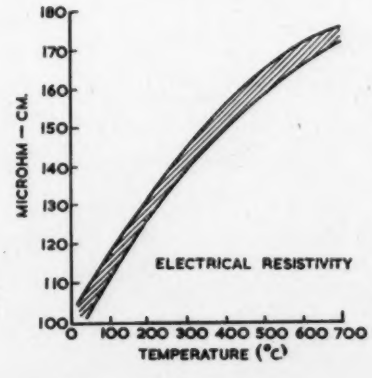



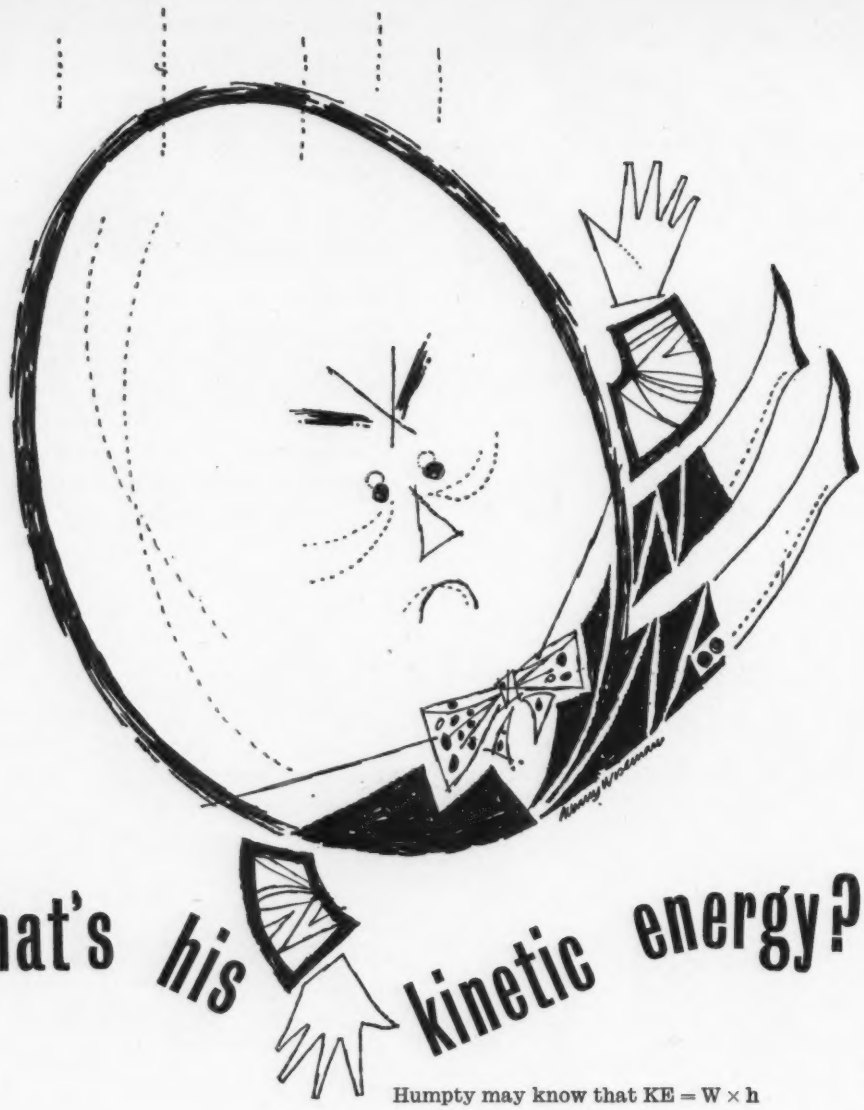



**EMD 5637** for further information



# what's his kinetic energy?

Humpty may know that KE = W × h
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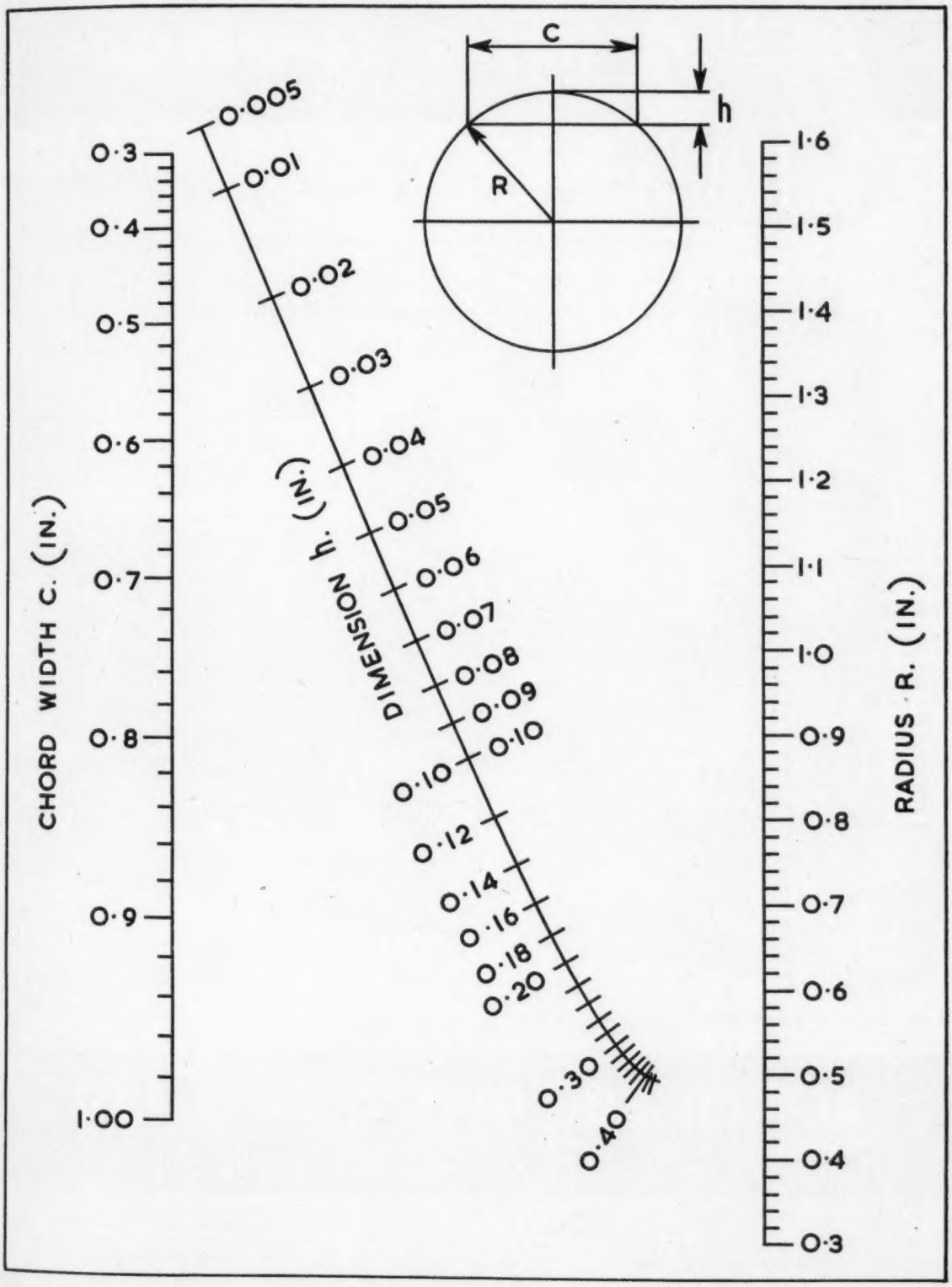
## NOMOGRAM FOR CHORDS

**Engineering Materials and Design**
DATA SHEET No. 55



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ROTARY COMPRESSORS
FROM 1/3-250 H.P.

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The Hydrovane principle was developed and introduced by Bullows in 1948 and has since been adopted by all the major manufacturers *throughout the World!*

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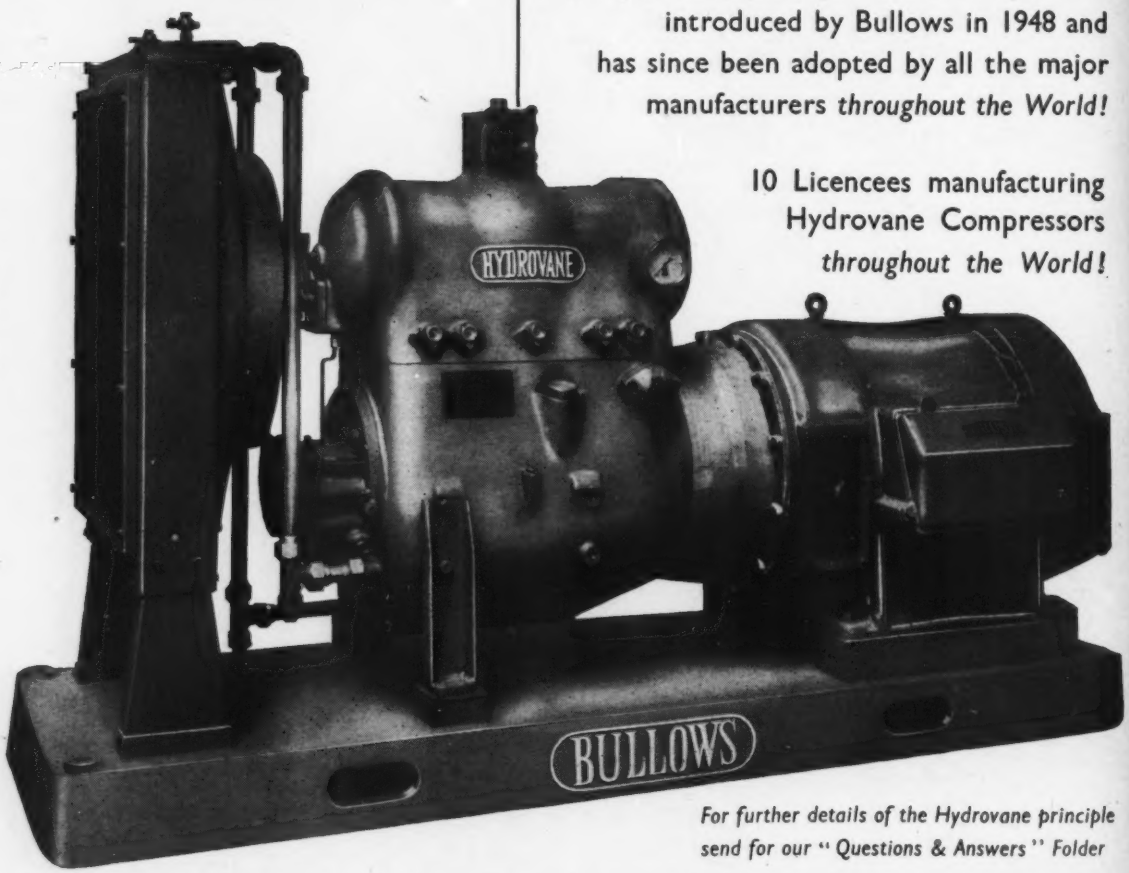


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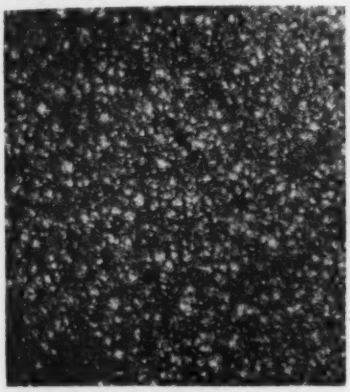
# WHAT'S NEW IN MATERIALS & COMPONENTS

## Hammer Wrinkle Finish

A new type of metal finish known as Detel hammer wrinkle is claimed to incorporate all that is best in both hammer and wrinkle finishes. The finish appears more like a fabric than a paint coating, and is said to have to a very high degree the property of obliterating surface blemishes and defects. Hammer wrinkle is a one-pack, stoving, spraying finish



with no complications, and requiring no difficult processes.

Actual uses and those envisaged include application to photographic and electronic equipment; domestic heating appliances; typewriters, duplicators and other office machinery; internal trim of motor vehicles; domestic air-conditioning equipment; and domestic lighting equipment. There is a range of colours available. Detel Products Ltd., Stonefield Way, Victoria Road, South Ruislip, Middlesex.

**EMD 5717** for further information

## Cleaning Fluid

Dasco Kleen in various forms is a cleaner which is claimed to meet the requirements of all types of machines and hard surfaces that need the removal of greases and dirt of any consistency. These cleaners were originally produced in the U.S.A., where notable results have been achieved, but they are now manufactured in the U.K.

The cleaner is a liquid detergent, and in its various types can be used in either cold or hot fresh water or with sea-water. The manufacturers stress some of its particular advantages as being that in mixing it requires no stirring, it is strong enough for the heaviest industrial cleaning, and will not remove paint or harm the skin. It can also be applied efficiently and economically on any surface with a spray gun.

Dasco Kleen 403 is an all-purpose industrial cleaner, and 407 (germicidal) is a combined cleaner-bactericide which is intended primarily as a machine tool coolant sump cleaner. 415 is an all-purpose marine cleaner which readily emulsifies with sea water without heating. 416 is a form of the product designed for efficient and economical degreasing—it does not require hot water to bring out its best, and a 10 per cent mix is said to remove greasy films almost instantly. D. A. Stuart Oil Co. (G.B.) Ltd., 11a Albemarle Street, London, W.1.

**EMD 5718** for further information

## P.t.f.e. Thread Sealant

Designed to function as a thread sealant in ribbon form, Hilflon unsintered p.t.f.e. tape is manufactured from the inert non-toxic thermoplastic polytetrafluorethylene, which possesses an exceptional thermal stability with a remarkable resistance to most known chemicals—acids, alkalis, oils, corrosive liquors and gases. Said to be unaffected by weathering or ageing, Hilflon tape is cleaner and easier to apply than conventional sealing compounds, which often involve the use of messy tins, bottles and brushes.

Available in a compact roll packed in a metal container, the tape is easily stored, transported and dispensed, thus removing the need for storing bulky containers and drums. No brushes are required, and just one layer of sealing tape makes a quick, easy application and provides a neat, clean joint. There is little chance of wastage due to negligence or exposure to the atmosphere, as the tape is said never to

harden. It is claimed to be unaffected by temperatures ranging from −230 to 260 deg. C. William Rose Ltd., Hilyn Works, Lockfield Avenue, Brimsdown, Enfield, Middlesex.

**EMD 5719** for further information

## Sprayed P.v.c. Coating

The availability in the U.K. of a new corrosion-resistant p.v.c. coating has been announced. An outstanding feature of this p.v.c. coating is its wide potential application in the chemical industry. Its resistant properties are said to range from alkalis to oxidising acids, and from fatty acids and their esters to petroleum hydrocarbons and alcohols. It can also be used on structural steelwork and factory plant, as a floor covering for workshops and industrial premises, for protecting concrete, brickwork, iron and non-ferrous metals against numerous types of corrosion, and in every industry concerned with the handling of corrosive materials. It is claimed to be diffusion proof, and can be employed under high mechanical stresses at operating temperatures up to 70 deg. C. Added advantages are its abrasion resistance and impermeability. BTR Industries Ltd., Herga House, Vincent Square, London, S.W.1.

**EMD 5720** for further information

## New Primer

Kingston Kurust primer is a new anti-corrosive treatment which has created international interest due to a combination of properties which are said to be unique. Designed for application to rusty surfaces, it combines rust neutralisation with permanent rust prevention. Kurust reacts with rust, changing it to iron phosphate and binding with it an anti-corrosive film formed of a special plastics, and metallic lead. It is anodic to the metal surface and is claimed to give full cathodic protection which prevents any further corrosion and is not liable to "rust spread" if the film is broken.

Kurust is said to resist flame heat, and it can be cut through by acetylene flame without damage. A. Sanderson & Co. Ltd., Kingston Paint Works, Hull.

**EMD 5721** for further information

## Reinforced Concrete Pipe

The Deckon system consists of a normal concrete pipe supported against hoop and beam stresses by an external coating of polyester resin reinforced with glass fibres. It is offered for main drainage and surface water schemes in all circumstances where the pipe has to be specially strengthened to meet a specified test load, or where flexibility, both transversely and longitudinally, is called for in meeting specific site conditions or design requirements.

The concrete pipe is first manufactured by the normal centrifugal process, using any suitable cement and to standard sizes and lengths. The glass fibre roving saturated in polyester resin is then applied mechanically to the pipe at a controlled helix angle. On completion, the pipe is cured at a controlled temperature.

In offering the Deckon pipe, special attention has been given by the makers to the question of joints. In this connection the problems of flexibility and watertightness, together with protection from corrosion, have been subjected to intensive research, and the use of the Deckon flexible collar rubber ring joint is recommended. This joint is built entirely in resin and glass fibre, and is designed to provide comparative flexibility to that of the pipe, and to give simplicity and speed in assembly. Sharp Jones & Co. Ltd., Bourne Valley Works, Parkstone, Poole, Dorset.

**EMD 5722** for further information

**FOR MORE INFORMATION**
about any of the products mentioned on these pages, please use the special reply card bound in this issue.

**READERS' ADVISORY SERVICE**
We shall be pleased to help readers who have difficulty in tracing sources of supply of materials or components.

# WHAT'S NEW IN MATERIALS & COMPONENTS

## Pure Elements

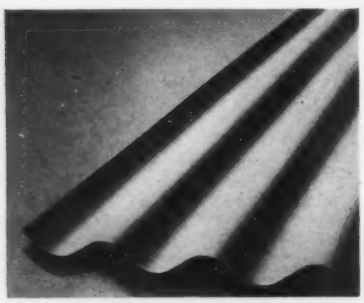
The difficult and dangerous task of producing ultra-pure phosphorus has been the subject of extensive investigations. It is now announced that, after many setbacks, techniques have been perfected which enable both red and white forms to be offered with a minimum purity of 99·999 per cent. The increasing applications of the phosphides of boron, gallium, indium, etc., will make this news of interest to semi-conductor manufacturers, as this is said to be the purest phosphorus available in the U.K.

Research into the development of zone-melting techniques for purifying other elements is also being carried out, and several metals are now available in ultra-pure form. Notable among these are indium, 99·9995 per cent pure, and boron, 99·9995 per cent pure. L. Light & Co. Ltd., Poyle Colnbrook, Bucks.

**EMD 5723** for further information

## Plastics-coated Steel

A plastics-coated sheet particularly suitable for use on industrial buildings and areas where atmospheric pollution exists is coated on both sides and all edges with a new polyvinyl chloride composition, Vynasol, developed by G. A. Willis Ltd. Produced in a range of eight colours, the sheets are said to have exceptionally high resistance to abrasion, impact, humidity and chemical attack.



Accelerated weathering tests have demonstrated that after the equivalent of twenty-five to thirty years' normal weathering the Vynasol coating still gives the sheets excellent protection.

The new sheets, which are available either corrugated or as "Scandinavian" tiles, are expected to have a far longer protective life than is currently available from any other form of steel cladding. Dorman, Long & Co. Ltd., G.P.O. Box No. 1, Zetland Road, Middlesbrough.

**EMD 5724** for further information

## Dyeline Paper

A new product known as Nuvatone, which is said to open up a new field in photo-copying, is a direct positive dyetype photo paper capable of reproducing line work and half-tone to give a black image on a fine matt paper surface. This means that copies of photographs and wash drawings can be made. A high degree of definition is claimed — the half-tone effect is actually produced by using a screened positive transparency. It can also be used for reproducing pen and ink drawings which have tone areas produced by adhesive tints. Direct copies can also be made from illustrations drawn on transparent or highly translucent base materials. J. Halden & Co. Ltd., Rowsley Works, Reddish, Stockport.

**EMD 5725** for further information

## New Form of Graphite

After two years' research, a process has been evolved for reducing the natural porosity of graphite.

The normal commercial processes for producing graphite result in a material which is able to withstand high temperatures, and resist the action of corrosive

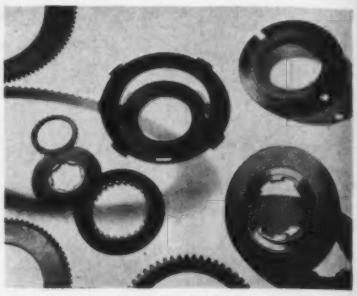
gases and fluids. Unfortunately, the nature of the chemical changes which this material undergoes in production makes it also very porous to both gases and fluids; this imposes certain limitations on its application in the engineering field and in consumer goods.

The new material which is being introduced is said to possess all the advantages of the old material, but to have largely got rid of the main disadvantage (porosity). Furthermore, the new material is claimed to be stronger and more resistant to oxidation. Its applications include the chemical industry, and equipment for handling molten metals. Other uses are high-temperature dies, bursting discs, pump seals, gland packings, rocket nozzle components and high-temperature bearings and bushes. It can also be used in the manufacture of transistors. Hawker Siddeley Nuclear Power Co. Ltd., Langley, Bucks.

**EMD 5726** for further information

## Friction Material

Sinterlink consists largely of sintered bronze particles which provide friction grip and at the same time transfer heat rapidly through the lining and metal-to-metal bond to the backing plate. This keeps the lining surface stable and cool. Small particles of "free" lead and graphite in the material provide a measure of dry lubrication which both reduces wear and stabilises friction. By the sintering process the even distribution of friction-raising additions such as ceramic particles is possible. The sintering process can also provide pores adequate for the escape of



excess oil from operating surfaces in many wet applications.

Sinterlink is said to have a stable coefficient of friction (i.e. its breakaway torque does not differ greatly from its running torque). This reduces the required margin of torque capacity over and above the full load rating. It is also claimed to have a constant friction value. This is an important factor in power transmission brakes and torque limiting device. Morgan-Mintex Ltd., Point Pleasant, London, S.W.18.

**EMD 5727** for further information

## New Hardboards

Two new materials, one of American origin, have recently been announced. The first, known as Duranite, is a specially tempered exterior hardboard which is claimed to stand up to continuous exposure under extreme conditions of humidity, without painting.

The second material, known as Benelex 70, is an industrial laminate manufactured by the Masonite Corp., of Chicago. It is now available in the U.K. Among the claims made for this material are high dielectric strength, high tensile and shear strength, extreme dimensional stability and resistance to many chemicals. It is also said to be easily worked, and can be routed, tapped and milled. It is available in many thicknesses from $\frac{1}{4}$-2 in., and in sizes up to 12 ft. long. The Wood Fibre Wallboard Co. Ltd., 8 City Road, Finsbury Square, London, E.C.1.

**EMD 5728** for further information

## Safer Rubber Hoses

Two new kinds of rubber pressure hose have been designed to give increased safety. One is a twin-bore type made of reinforced rubber, each bore having a diameter of $\frac{5}{16}$ in. By splitting the tubes apart at the end of the hose, two connections can be made, while only one length of hose trails between gas cylinders and equipment. Twin hoses with a range of bores of up to $\frac{1}{2}$ in. are also available.

The other new type of hose is specially designed for use with propane. This type is lined with nitrile or neoprene, which are not affected by liquid propane and will therefore give longer life and increased safety. It is stocked in a range of sizes. British Industrial Gases Ltd., 700 Great Cambridge Road, Enfield, Middlesex.

**EMD 5729** for further information

# WHAT'S NEW IN COMPONENTS

## Unbreakable Socket

The Briticent four-way, 5-amp. fused socket outlet unit is claimed to be completely safe and unbreakable. It comprises four 5-amp. sockets, and is available in either hard rubber or neoprene. It is provided with an unbreakable cord grip that firmly holds the cable without crushing it. The fuse is easily accessible and can be quickly replaced. The cover is held with five countersunk brass screws,

which screw into brass inserts moulded in the base. The sockets are formed from brass strip which is continuous from pin socket to pin socket, set in recesses and channels in the solid rubber or neoprene base. Designed for the roughest treatment, it is suitable for use on the workshop floor or for securing to walls, panels, etc. British Central Electrical Co. Ltd., Briticent House, 6/8 Rosebery Avenue, London, **E.C.1.**

**EMD 5730** for further information

## Transistorised Two-step Controller

The Metrawatt transistorised controllers are available with moving coil and cross-coil type movements, and can therefore be used for the regulation, control and supervision of all quantities which can be measured by movements of these types. One of their principal applications is in temperature control, used in conjunction with a thermocouple or a resistance thermometer. Owing to the fact that they act with zero lag (whereby they differ from the chopper bar type of controller), these controllers are said to be useful for all types of duty where the controlled variable, e.g. temperature, is subject to rapid fluctuation.

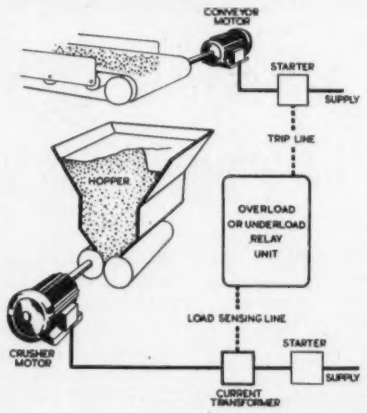
The Metrawatt controller measures the value of the controlled condition by means of an electrical measuring instrument. The pointer arm of the electrical movement has a small aluminium flag. As soon as the measured value changes, the flag enters the air gap between two inductors, thus upsetting the coupling between them and interrupting the action of a transistor-oscillator. The inductor coils are fixed to the pointer through which the desired value is set. On reversal of the pointer motion, the flag leaves the air gap and the oscillator action re-starts. After rectification the oscillator current controls a mercury relay or a small contactor.

The instruments are contained in a rectangular standard case of the flush-mounting type measuring $7\frac{9}{16}$ in. × $4\frac{1}{16}$ in., and the desired values or limits are set via flexible shafts by means of adjuster screws on the top part of the case frame; length of scale is approximately $5\frac{1}{4}$ in. The sensitivity of the controlling equipment is ±0·5 per cent of the scale length, and the mains voltage 115 or 220 V. Permissible mains voltage fluctuation is ±15 per cent, and power consumption approximately 3 VA. per pick-up system. Controller output is 1 W. per pick-up system, which is adequate for direct connection of a mercury relay or a small contactor with three changeover contacts. Room temperature fluctuation tolerated is −10 to +50 deg. C. Metrawatt A.G., Nürnberg.

**EMD 5731** for further information

## Overload and Underload Relays

In the handling or processing of bulk materials, it is often required to stop an electrically driven unit before it becomes seriously overloaded, and to restart it when conditions have been restored to normal. The illustration shows an Elcontrol overload relay being used in such an application, viz. on a crusher. By using such a relay in the crusher motor circuit, it is possible to stop the conveyor when the crusher motor current reaches a predetermined value. This gives the crusher a chance to clear itself.




The Elcontrol relay can also be used as a direct on/off control—e.g. in the case quoted, the crusher motor itself could be switched off at a pre-set current loading, a signal could be operated, and manual restart could be made when the overload condition had been cleared. The units are supplied with a withdrawable chassis housed in a steel case with a hinged lid, and fitted with signal lamp indicating "relay energised".

The OR 3 is an overload relay for 200-250 V., 50-60 c/s supply. It is supplied with separate current transformer rated for 5, 100 or 250 amps.

The UR 3 is an underload relay unit for 200-250 V., 50-60 c/s supply. It is also supplied with transformer. Elcontrol Ltd., Wilbury Way, Hitchin, Herts.

**EMD 5732** for further information

## Frequency Meter

The new direct-reading TD1 frequency meter is capable of producing and measuring any discrete frequency between 1,000 c/s and 3,000 mc/s, and has a stability, depending on the crystal chosen, of 2 parts in $10^{-8}$ to 4 parts in $10^{-10}$. Suitable for driving and checking single sideband systems, exciting nuclear magnetic resonances, single transmission navigation aids and laboratory references for scientific, industrial and educational laboratories, the instrument has an output capable of driving, and facilities are provided for plugging in an external counter.

The TD1 is transportable, and the first model incorporates a crystal allowing an accuracy of 2 parts in $10^8$ after 1 hr. The internal impedance is 75 ohms, output voltage on fundamental frequencies is 100 mV., input voltage on fundamental and harmonic frequencies is 1 mV. and spurious frequency level is −80 dBs. Voltage changes, valve deterioration and physical shock are said to effect no appreciable change in frequency or phase. Telemechanics Ltd., Telemax Works, Brokenford Land, Totton, Hants.

**EMD 5733** for further information

## Toroidally-wound Transformer

A new toroidally-wound ½-amp. 120-W. unit, claimed to be the first of its kind in the field of variable transformers, is announced by Phillips. Known as the 88.709.59, it is designed for use on 220-V. or 240-V. 50 c/s a.c. supply, and will provide an output voltage continuously variable from zero up to 250 V. at a nominal current of 500 mA. Available as a manually-operated unit for panel mounting, the new transformer can be supplied in motor-driven form if required. U.K. Research & Control Instruments Ltd., Instrument House, 207 King's Cross Road, London W.C.1.

**EMD 5734** for further information

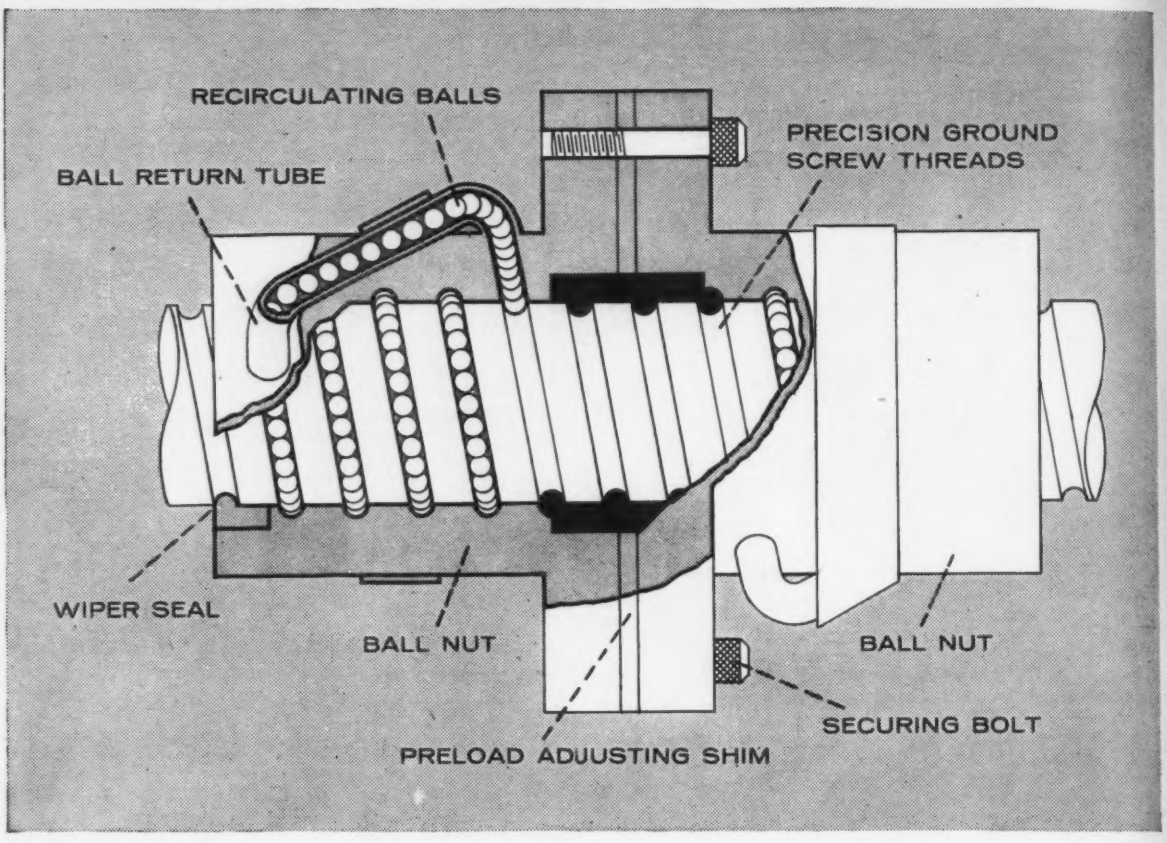
## Tropicalised Motor

A low-priced shaded pole motor, which is claimed to be produced to a more stringent specification than is usual, has been introduced. The motor is fully tropicalised to operate in virtually any weather conditions, and has been designed to meet Ministry of Aviation Spec. DTD 1085/B. The motor is continuously rated (without air stream cooling) at 12 W. with 2 W. output, and operates on 230/115 mains voltage to a maximum of 2,700 r.p.m. A 50-W. version with an output of 12 W. is also available for use where more power is required. The British Vacuum Cleaner & Engineering Co. Ltd., Goblin Works, Leatherhead, Surrey.

**EMD 5735** for further information

## Please Note!

**We receive many reader enquiry cards on which the reader has omitted to fill in his name and address. In order to avoid disappointment we remind readers that names and addresses should be included on *each* card.**




# Beaver pre-loaded ball screws, up to 95% efficient, operate at—52°C to over 400°C with no backlash

Bristol Siddeley Engines Limited produce Beaver* pre-loaded ball screws. These ball screws achieve a minimum efficiency of 90% and they can operate within a temperature range of—52°C to 400°C without lubrication, and up to 170°C when lubricated.

Machined and ground to the highest standards of precision engineering Beaver pre-loaded ball screws greatly increase transmission efficiency. They reduce the power required for actuation by as much as 80%, when converting rotary drive into linear output or force input into torque output. By eliminating backlash, with pre-loading, they give precise control over very small increments of motion and a high response frequency. And when compared to conventional screw mechanisms, they provide a predictable operating life which is much longer, require much less maintenance and give more trouble-free operation.

**Basic design application analysis**

Bristol Siddeley engineers make an exhaustive analysis of each specification. And each unit is specially designed for its particular application. Beaver ball screws are made automatically reversible or with controlled "no-back," with multiple or single circuits. Beaver pre-loaded ball screws have been proved as the most efficient method of converting rotary into linear thrust in over 2,700 engineering applications in many branches of industry. They have been designed already with rated operating load capacities of 370,000 lb (825,000 lb maximum static load) but the maximum potential operating load is, in most cases, limited only by the requirement.

**Bristol Siddeley Beaver ball splines** have been developed to eliminate the disadvantages of conventional splines. The designs are very effective in minimising friction, particularly when high torsional and bending loads are imposed during linear movement.

**Complete technical and manufacturing co-operation with Beaver Precision Products Inc, Detroit.*

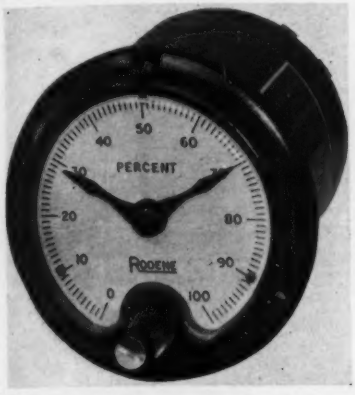
For further information please write to J. B. Starky, Sales Manager (Ball Screws and Splines), Bristol Siddeley Engines Limited, PO Box 17, Coventry, England.

**BRISTOL SIDDELEY ENGINES LIMITED**

# WHAT'S NEW IN COMPONENTS

## New Batching Timer

A new range of timers, designed to control batching and mixing plants such as those used for road-making materials, but having applications in other types of equipment, is announced. In cases where the materials are delivered to a




mixer of fixed capacity, it is best to think of the quantity of each as a percentage of that capacity, and for this reason the range of timers is calibrated in percentage. The timers should be set so that the total of their dial readings equals 100 per cent. To ensure this, each timer has geared to its setting pointer an accurate potentiometer, and these can be interconnected so as to show on a moving coil meter the total of their settings.

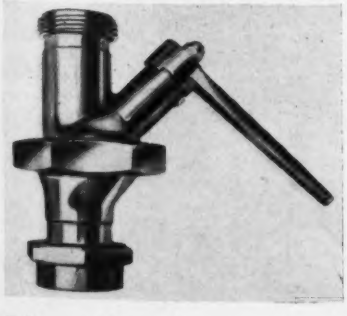
These timers have contacts that allow many methods of operation, but for this purpose they can be connected to start on receipt of a pulse; to close a contact for the timed period; and to give a further pulse at the end of the timed period which can start the next timer in the chain.

Setting is by a pointer moved by a knob or by a removable key. A second pointer moves to show the progress of the timing. Made by Rodene Electrical Co Ltd., distributors are D. Robinson & Co. Ltd., 717 London Road, Hounslow, Middlesex.

**EMD 5736** for further information

## Hygienic Valve

The Paravalve has been developed for the in-place cleaning of pipelines in food and chemical plant, and is designed to operate at high pressures and provide efficient flow control characteristics com-



bined with non-galling action and freedom from jamming when handling hot liquids.

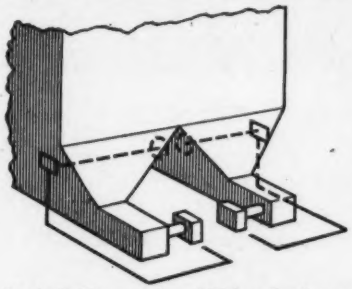
The unit, which is made from stainless steel, is a form of butterfly valve fitting into a resilient rubber seat which is located in the wall of the body. This seat is interchangeable and easily renewable, and does not rely upon finely machined surfaces to make a positive seal; it is not therefore liable to accidental damage.

By turning the handle through 180°, the plane of the valve is rotated from a vertical to a horizontal position above the centre of the pipeline. The spindle of the valve, which is sealed by a hygienic rotary joint, does not rise through the packing and therefore avoids any possibility of atmospheric contamination. The flow through the valve, with a constant inlet pressure, is almost directly proportional to the movement of the handle. Pressures of up to 100 p.s.i. may be handled, provided that the product pressure is applied against the valve face. The valve is available in 1-in., 1½-in., 2-in., 2½-in. and 3-in. sizes with Type S.P., R.J.T. and American 3a connections. The A.P.V. Co. Ltd., Manor Royal, Crawley, Sussex.

**EMD 5737** for further information

## Radiation Switch

The Simcar radiation switch has been designed to operate when radiation either begins or ceases to fall on it. The source of radiation is normally a small amount



of cobalt 60 or cæsium 137 in a lead container. For certain applications it can simply be a patch of radioactive paint of low activity. The design uses the principle that if material between the switch and the source is replaced with a material of lesser or greater density, there will be a correspondingly higher or lower degree of radiation absorption. The beam of radiation from the source will either be prevented from reaching the switch, or will be allowed to reach it.

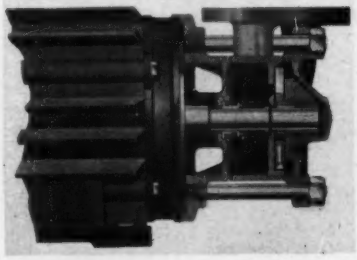
The radiation source is housed in a lead container of special design which enables a narrow beam of radiation to be emitted in the direction of the switch, but eliminates stray radiation. A valve is provided to cut off the beam, and for extra safety this can be controlled remotely or mechanically interlocked with access doors. The switch is intended for use with level indicators, alignment controls, counting devices, alarms, etc. A. M. Lock & Co. Ltd., Prudential Buildings, 79 Union Street, Oldham, Lancs.

**EMD 5738** for further information

## MoPump for Boiler Feed Duties

The new SC MoPump has been developed to meet the demand created by the popularity of the "package" boilers, where conventional multi-stage centrifugal pumps are not usually an economic proposition due to a low efficiency at the duty point and the higher cost of manufacture.

The internal design of the SC MoPump can be described as being of the side-channel regenerative type. Particles of liquid leave and re-enter the space between the rotor blades several times be-



fore leaving the pump casing. The energy thus imparted to the liquid in the form of pressure is correspondingly greater than that generated by a conventional unit with a similar size impeller at the same speed. The type of seal used, a Crane type 2 with ESN seat, is situated at the low-pressure end of the pump, and has an extended surface seat which allows maximum heat dissipation from the sealing faces and enables the pumps to be used for liquids up to 93 deg. C.

Normally the pumps are supplied with branches going vertically upwards in a common direction, but three alternative positions with four branches are available. 1-in., 1½-in., 1½-in. and 2-in. bore branches are available in single-stage and two-stage units. Any make of drip-proof motor or totally enclosed motor of BS frame size and suitable shaft extension can be used. Rhodes, Brydon & Youatt Ltd., Reddish Engineering Works, Stockport, Cheshire.

**EMD 5739** for further information

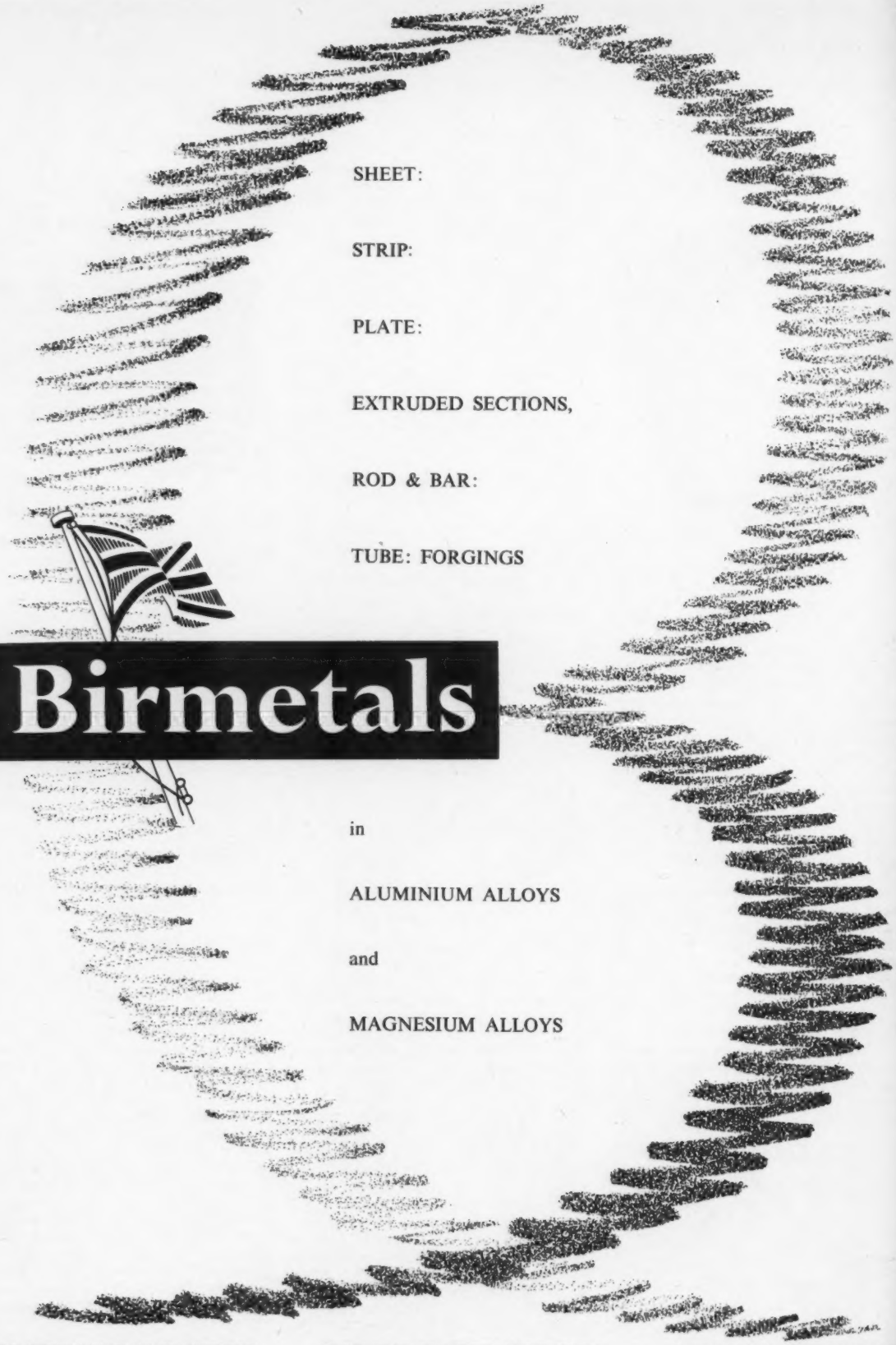
## Pressure Relief Valve

The Kernon deadweight pressure relief valve, which is suitable for both pressure and vacuum stills and all classes of chemical plant under corrosive conditions, is provided with a flexible diaphragm in p.t.f.e. in the upper half of the valve body which serves as an oil reservoir. The oil serves to seal the valve spindle.

The valve is claimed to be capable of withstanding high temperatures for long periods unattended. A special dash-pot feature allows for rapid lift but floating action on closure, thus preventing damage to valve and seat. The body of the valve is obtainable in cast iron, stainless steel or other metals, the valve and seat being available in stainless steel, gunmetal, phosphor bronze, nickel alloy, etc. 1-in., 2-in., 3-in. and 4-in. sizes are available from stock in cast iron. A discharge capacity of between two and three times that of conventional spring-loaded relief valves is claimed. Robert Harlow & Son Ltd., Heaton Norris, Stockport.

**EMD 5740** for further information

**EMD 5640** for further information




**BIRMETALS LIMITED · WOODGATE WORKS · BIRMINGHAM, 32**
*BM 293*

# WHAT'S NEW IN COMPONENTS

## Portable Insulating Oil Filters

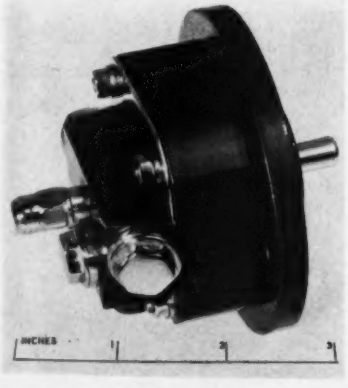
The P8 model in the Stream-Line range of filters is portable, and has its own pumping set. The filter is of robust construction, and is claimed to remove contaminants from dirty oil at rates between 50 and 100 gall./hr. when dealing with oil at ambient temperatures of 12·7-15·6 deg. C. The dielectric strength of the filtered oil is claimed to satisfy the requirements of British Standards for new oil.

The filter is easily transported by one man, and, being unheated, can be operated where an electrical supply for heaters is not available. Provided any free water is decanted before filtration, the P8 filter can deal with the remaining traces of moisture up to a maximum quantity of about three-quarters of a pint. The filter packs can be dried without removal from the filter whenever a CN type Stream-Line filter is available. Stream-Line Filters Ltd., Henley Park, Guildford, Surrey.

**EMD 5741** for further information

## Hydraulic Motor

A new high-speed hydraulic motor recently introduced consists of a bronze cylinder block in which are housed seven radially disposed pistons. The cylinder rotates around a hardened steel distributor stalk and the pistons bear against a circular track which is positioned eccentrically to the centre of the stalk. Thus the pistons travel in and out as the cylinblock rotates. Oil supply and return passageways are provided up the centre of the stalk, and the porting is so arranged that the pressure passageway is connected to those pistons which are moving outwards and the return to those which are moving inwards.




The method of mounting and of connecting the supply can be adapted to suit individual requirements. The overall measurements of the pump are 3 in. dia. × 2⅝ in. long. Maximum speed is 20,000 r.p.m., and maximum pressure is 1,000 p.s.i. Output torques at 1,000 p.s.i. inlet pressure are: 4,000 r.p.m., 1,100 gm. cm.; 10,000 r.p.m., 950 gm. cm; 15,000 r.p.m., 820 gm. cm.; and 20,000 r.p.m., 700 gm. cm. Boulton Paul Aircraft Ltd., Wolverhampton.

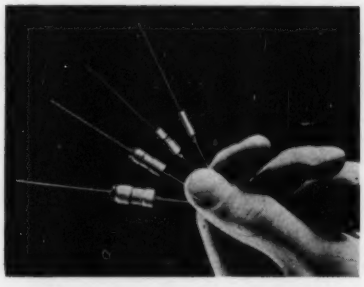
**EMD 5742** for further information

## Miniature Aluminium Electrolytic Capacitors

A new range of miniature electrolytic capacitors, type L.S.R., has been introduced. Designed especially for high-frequency application, these components are particularly suitable for transistor circuitry where low impedance at 10 kc/s or higher is mandatory.

The working characteristics of the type L.S.R. capacitors make them ideal for use in transistor computers where discharge current pulses of 1 microsecond duration are encountered. Under such conditions low internal resistance is required and, during the pulse, the internal resistance calculated from the voltage drop across the capacitor should not exceed 0·2 ohm.

The range at present comprises seven ratings with working characteristics extending from 200 mfd. at 3-V. working to 12 mfd. at 150-V. working, the capacitance being measured at 50 c/s. The power factor varies with the rating of the



capacitor and for a 200 mfd. 3-V. unit is 70 per cent, whereas for a 12 mfd. 150-V. unit it is 18 per cent, both measured at a frequency of 10 kc/s. An exceptionally good performance at −40 to +40 deg. C. is claimed. At the low temperature, for instance, a 40 mfd. 25-V. unit has a power factor better than 50 per cent.

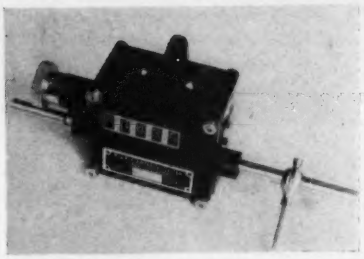
This low internal resistance type of miniature etched foil capacitor is extremely compact, and the present range is contained in an aluminium can measuring only ¼ in. in length and ¼ in. in diameter. All available ratings can be supplied in an insulating plastics sleeve. The Plessey Co. Ltd., Ilford, Essex.

**EMD 5743** for further information

## All-plastics Needle Valve

A small needle valve, primarily intended for use with Wade couplings, is now available. It is constructed from styrene/butadiene acrylonitrile, and is available for use with plastics tubes of the following sizes: ¼ in. o.d., $\frac{5}{32}$ in. i.d.; $\frac{5}{16}$ in. o.d., ¼ in. i.d.; ⅜ in. o.d., ¼ in. i.d. The valve is recommended for use with fluids at 0-300 p.s.i., and gases at 0-100 p.s.i. Each valve is designed with spigot support for the tubing and knurled coupling nuts for hand tightening. Barflo Ltd., 56 Cavendish Place, Eastbourne, Sussex.

**EMD 5744** for further information



## Impervious Counter

The illustration shows a new type of robust revolution counter for the food and canning industries, designated the 30-2 rotary or ratchet counter. It is claimed to be completely impervious to steam or moisture, since it has drainage holes in the case, thus making it suitable for steam sterilising conditions. B. & F. Carter & Co. Ltd., Albion Works, Bolton.

**EMD 5745** for further information

## Indexing Mechanisms

The Manifold Mk. 2 range of indexing mechanisms has been specially developed for use in production machinery. Each mechanism consists of two co-operating elements, the driven member being a turret which bears a number of radially arranged and equally spaced rollers. The driving member, being a cam of concave globoidal shape, is similar in principle to a worm, since it has a thread which engages with the turret rollers. Part of the thread is straight and the remainder form a helix of varying pressure angle. The straight portion provides the necessary dwell period during which production operations are performed.

The units are claimed to be manufactured to extreme limits of accuracy, and to be capable of operating at speeds as high as 750 c/s per min. Provision is made for a wide variety of applications, with as few as four stops for each complete revolution of the turret. The manufacturers have developed special cam-cutting machinery for making the globoid cams, and special versions to customer's requirements can be obtained to special order. A

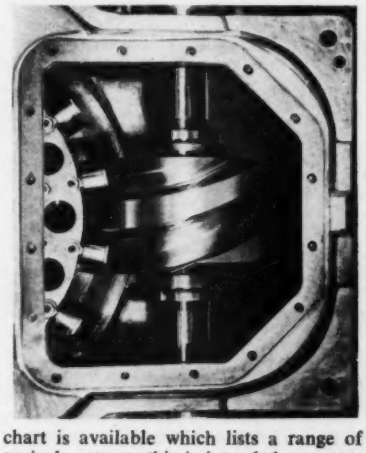
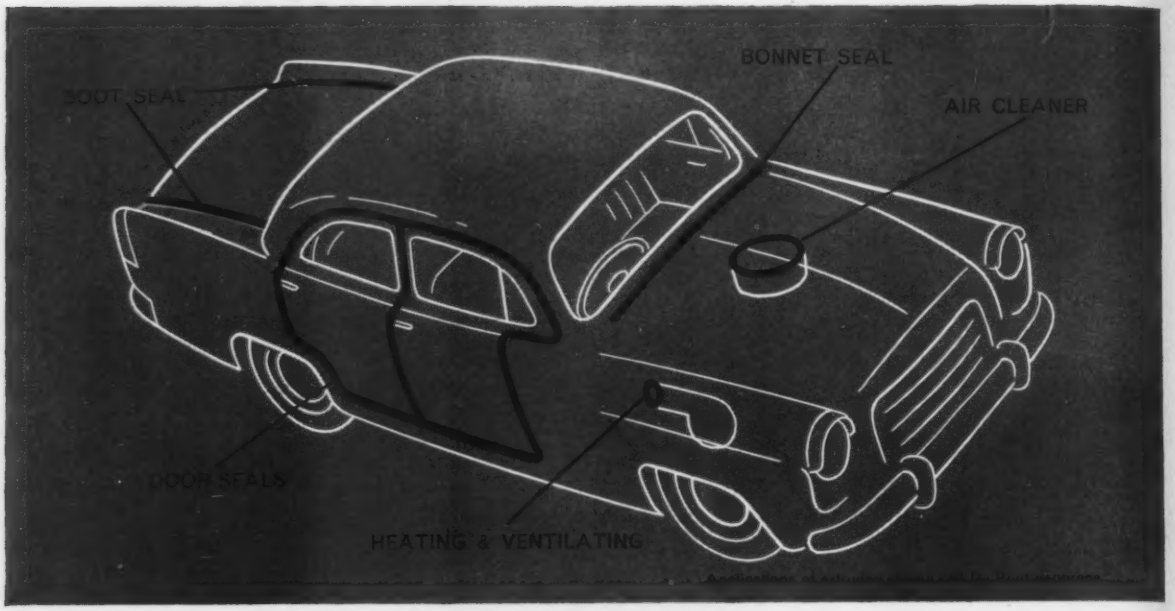
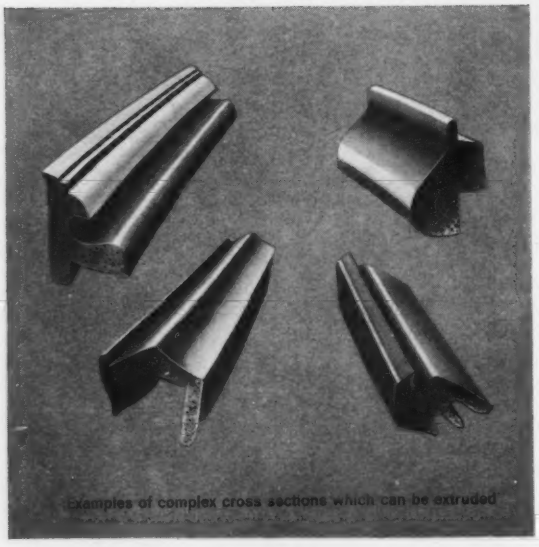


chart is available which lists a range of typical systems; this is intended as a preliminary guide. Manifold Machinery Co., 660 Great Cambridge Road, Enfield, Middlesex.

**EMD 5746** for further information

# A new and improved body seal: EXTRUDED CLOSED CELL DU PONT NEOPRENE





Examples of complex cross sections which can be extruded

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# WHAT'S NEW IN COMPONENTS

## New P-N-P Alloy Transistors

Two new transistors, types 2S301 and 2S302, are the first in a range of silicon alloy junction devices. Their p-n-p structure makes all-silicon complementary circuitry possible for the first time, using Texas n-p-n silicon transistors. A particular feature of both the high-voltage version, the 2S301, and of the 2S302 is the extremely low saturation (bottoming) voltage. This, with all the advantages of silicon, is similar to that for germanium transistors.

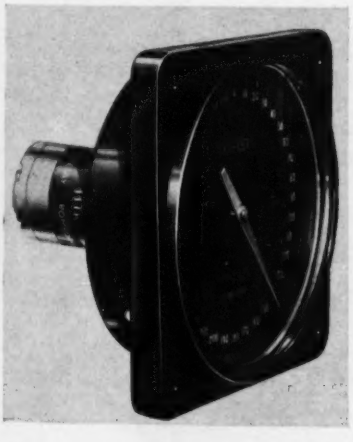
The 2S301 has a voltage rating of 60 V., an $h_{fe}$ spread of 10-40, and an alpha cut-off frequency of 1 mc/s. Equivalent figures for the 2S302 are 25 V., 15-50 and 500 kc/s. Typical saturation (bottoming) voltage is extremely low at 130 mV., peak collector current rating is 100 mA., and total dissipation is 250 mW. In addition, being silicon, they have an operating temperature range of −55 to +150 deg. C.

These general-purpose transistors are housed in the robust welded steel Jedec To-5 case, and have a wide field of application. Texas Instruments Ltd., Dallas Road, Bedford.

**EMD 5747** for further information

## Dial Indicators

Two robust, square flange indicators, for use wherever angular or linear information is required to be displayed or repeated, are now added to the range available from Ketay Ltd. The new indicator has a 3-in.-dia. dial and operates by a.c. synchronous transmission. It is suitable for incorporation in test rigs and, industrial process equipment, or for any other application where accurate remote indication is needed.



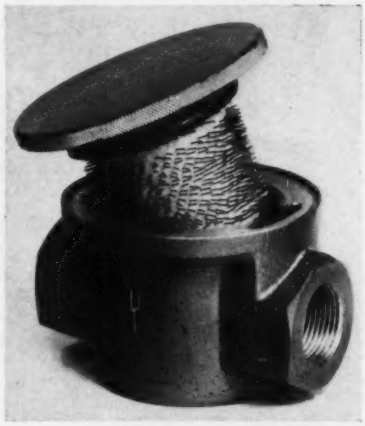
Standard scale calibration is 0-360 deg. in 2-deg. intervals, but alternative scaling to customer's requirements can be provided at no extra cost. Well-damped size 11, 15 or 18 synchro torque receivers are used so that the pointer has a very short settling time. Normal accuracy is ±1 deg. Ketway synchro torque transmitters complementary to the synchro torque receivers specified are available for 50-60 or 400 c/s operation, and special transmitters can be supplied where several indicators are required to operate from one transmitter.

For coarse-fine indication a 7½-in. square flange version is being produced. This model uses two size-18 torque synchros which operate in conjunction with a coarse-fine transmitter unit. Ketay Ltd., Eddes House, Eastern Avenue West, Romford, Essex.

**EMD 5748** for further information

## Mechanical and Magnetic Microfilter

The Micro-S-Filter illustrated is one of a range of such filters embodying a number of interesting features. They are intended for high-efficiency filtration of oil and hydraulic fluids. Although the



filter is considerably smaller than a comparable filter using sieve paper elements as a filtering medium, it is essentially simple and is claimed to be unchokeable. No relief valves and exchange cartridges are necessary, and the life of the filter is claimed to be practically without limit.

The liquid to be filtered enters the filter chamber and flows around the filter element. Owing to the flow, all kinds of dust and chips are forced into the interior path where they are stopped and removed, partly by highly magnetic needles and partly by the filtering material. A large number of sizes, with screwed or flanged connections, are available. Stelzner & Co., Postschleissfach 1700, Essen.

**EMD 5749** for further information

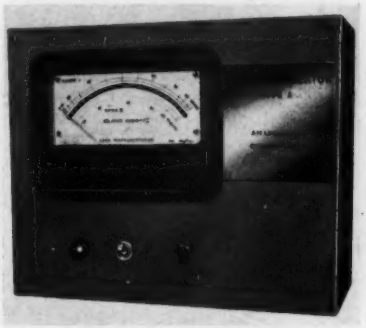
## Nylon Cable Glands

The Elkay range of cable glands has now been extended to include a version with a long screw thread for inserting through thick panels and locking with the appropriate nylon lock nut. The screw thread on these new glands is ¾ in. long, and they can thus be inserted through plates up to ½ in. thick, allowing ¼ in. for securing with a lock nut. Forty-nine variations in size and colour are available. Elkay Electrical Manufacturing Co. Ltd., 42 Woburn Place, London, W.C.1.

**EMD 5750** for further information

## Relative Humidity Indicator

The Lock relative humidity indicator uses a new type of plastic sensing element, having a specially prepared conducting surface, which is claimed to provide an accurate and reliable humidity measurement over the range 10-100 R.H. Excellent long-term calibration stability is also



claimed, and the sensing element is said to be unaffected by most chemical vapours or by prolonged exposure to 100 per cent R.H. conditions. The standard indicating meter has a scale length of 5 in., and is calibrated directly in percentage R.H. with an accuracy of 3 per cent. A check position enables the calibration of the instrument to be checked and any slight long-term variations compensated for.

The measuring circuits and indicating meter are housed in a dust-tight case which can be provided for either flush panel or wall mountings. Mains supply of 200-250 V., 50 c/s is standard; other mains supplies to order. The element can be used over the range −5 to 80 deg. C. A. M. Lock & Co. Ltd., Prudential Buildings, Union Street, Oldham.

**EMD 5751** for further information

## Reducing Valve

A high-pressure reducing valve, claimed to be capable of an extremely fast response rate with a high degree of stability under the most difficult conditions, has been introduced. Known as the PAS.227, it is claimed to be capable of accepting an increase of pressure on the inlet side from zero to 4,000 p.s.i. in 2 milliseconds, controlling the pressure in the downstream system, consisting of 8 in. of ¼-in. o.d. pipe plus 3 cu. in., and stabilising in 0·2 sec. It has an inlet pressure range of from 500-4,000 p.s.i., while the outlet pressure is 400 ±25 p.s.i. over a flow range of from 5-65 cu. ft./min. The total overshoot of pressure in the downstream system is less than 140 p.s.i. above control pressure.

The valve is designed to operate consistently without servicing for up to five years. It has a temperature range of −58 to +110 deg. C. Accelerations of up to 20 g. can be applied without affecting outlet pressure characteristics.

The PAS.227, which embodies an integral filter, is 4¼ in. long and has a diameter of 1¼ in. It weighs approximately 1 lb. The Hymatic Engineering Co. Ltd., Redditch, Worcs.

**EMD 5752** for further information

**EMD 5642** for further information

# we hardly recognise ourselves

The various guises our tubes appear in after they leave us are—to say the least—numerous. The list of industries, let alone products, in which they play a part is almost as wide as Industry itself. A few samples: Refrigeration; Electrical and Allied Industries; Radio and Electronics, General Engineering. In products just let's say Ellay Small Diameter non-ferrous tubing are found everywhere small metal tubing is used.

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In general purpose, close or precision tolerances
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A.P. 30

# WHAT'S NEW IN EQUIPMENT

## New Welding Meter

A new meter for a.c. welding production, research and development is designed to measure the electrical conditions in a welding arc. It consists of a watthour meter, ammeter, voltmeter and protective relay all housed in a compact case (16¼ × 5¼ × 6½ in.), suitable for switchboard or wall mounting. A four-range current transformer for stepping down the current from 100, 300, 500 or 1,000 A. to 5 A. can also be supplied.

The watthour meter has a pointer which moves over a 4-in. dia. scale, one revolution of the pointer being equivalent to 100 watthours at 100/5 A. For other ratios a multiplying constant must be used. The pointer can be re-set to zero after each welding operation by depressing the knob in the meter glass and turning anti-clockwise. The total watthours are shown on the meter register.

The ammeter and voltmeter are of the 4-in.-square moving iron pattern. Zero adjusters are accessible through cover plates in the meter window. The voltmeter is scaled 0–120 V., and is marked 1 V. per division between 20 and 45 V., the normal arc voltage range. The ammeter is scaled 0 to 120 A., and read direct for a current transformer ratio of 100/5 A. As for the watthour meter, a constant must be used for other ratios. The relay is reset by a push rod on the underside of the case. The English Electric Co. Ltd., English Electric House, Strand, London, W.C.2.

**EMD 5753** for further information

## Pneumatic Saw and File

A new lightweight production tool, accommodating either a saw blade collet or a file chuck, has been introduced. This new tool, the CP 3017F, is operated by a unit-type Power Vane air motor, the high torque of this unit being converted to a reciprocating motion by a cam follower. The speed of operation of the saw blade or file is 1,500 strokes per min., the stroke length being ¼ in. Controlled starting is effected by the throttle, which is of the graduated poppet valve type with neoprene seating, while a built-in speed regulator is incorporated to adjust the cutting rate to the requirements of the task in hand. An oil reservoir is located in the handle to supply lubricant to the motor, lubrication of the gearing being carried out through a filter plug without dismantling the gearing. In order to keep cuttings clear of the work, the motor exhaust air is directed downwards through the nose of the tool to impinge on the blade or file.

The weight of the 3017F is 5 lb., and the overall length 14½ in. The air inlet thread size is ¼ in., and the minimum hose size $\frac{1}{16}$ in. Standard equipment supplied with the tool consists of one saw collet, five general-purpose metal cutting blades, one work rest, one file chuck and guard and one Allen wrench. Consolidated Pneumatic Tool Co. Ltd., 232 Dawes Road, London, S.W.6.

**EMD 5754** for further information

## Illuminated Pocket Magnifier

The Glo-Mag illuminated pocket magnifier has a power of 44D (11 times magnification). It is precision-made of strong lightweight plastics material and fits comfortably into the hand. There is a thumb-operated push-button switch which cannot be left on accidentally.

The Glo-Mag is especially suitable for inspection work, and is designed to be held close to the eye. It is powered by two Ever Ready U.12 batteries, and weighs only 2 oz. complete. Available colours are maroon, dark blue or green. Combined Optical Industries Ltd., Plasta Works, Bath Road, Slough, Bucks.

**EMD 5755** for further information

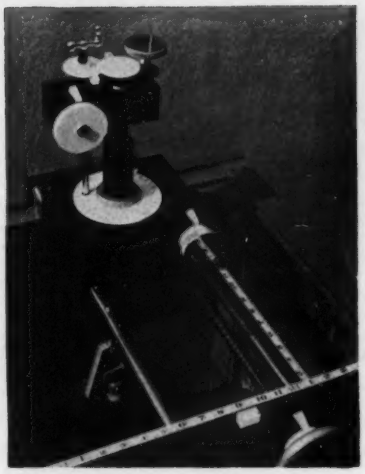
## Probe Manipulator

The Ultrasonoscope range of probe manipulators has been developed at the request of the British aircraft industry. Experience has shown that inspection by the immersion technique often requires the ultrasonic beam to be directed other than normally into the material being tested.

The latest addition to the manipulator range, the Mk. 4, is usually supplied fitted to a supporting gantry, the construction of which is flat and can be dimensioned to suit customers' existing inspection tanks. Alternatively, the manipulator and inspection tank can be supplied as a complete unit.

Displacement along and across the gantry is achieved by means of hand-wheel operation through lead screws. A hand-wheel control mounted on the front of the manipulator allows a movement of ½° about the vertical axis to be recorded. In the horizontal axis, probe movement from a position approximately 20° to the vertical with the crystal face towards the couplant surface through 200° can be obtained by the use of a ball handle at the top of the manipulator. Provision is made so that the probe crystal face can be aligned parallel to the specimen with the rotation dial readings set to zero.

The mechanisms associated with the rotational probe movements are self-compensating for wear. Adaptors are supplied to suit all standard immersion probes made by the Ultrasonoscope Co. Special adaptors can be made to order. Ultrasonoscope Co. (London) Ltd., Sudbourne Road, Brixton Hill, London, S.W.2.



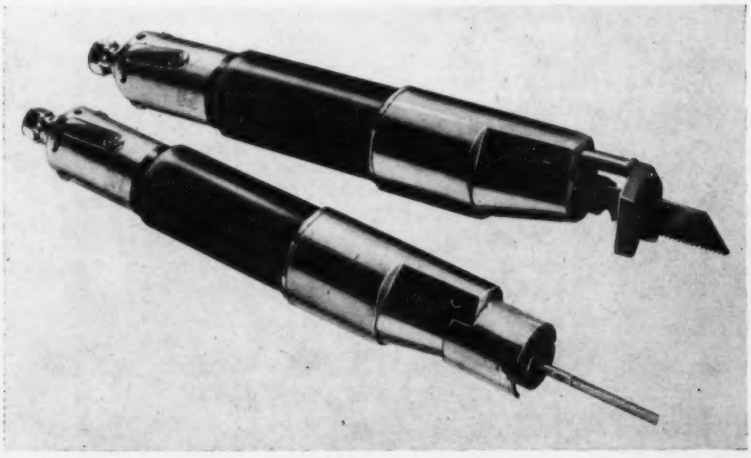
**EMD 5756** for further information

## Electrostatic Coating Equipment

H. R. Noble Ltd. have become the U.K. distributors for Ionic Electrostatic Corp., of the U.S.A. They will handle the entire line of Ionic electrostatic coating equipment, which includes three basic automatic electrostatic systems employing air and high-speed centrifugal atomisation adaptable to all types of conveying systems, including monorail, overhead, spindle, roller, belt and slat. Ionic's recently announced Model 10 high-speed centrifugal-type electrostatic hand gun, which works by a new electro-centrifugal deposition technique, will also be available.

The design of Ionic electrostatic equipment is claimed to permit unique adaptation of electrostatic techniques to cover conductive, water-base, and a wide range of other paints and coating materials without difficulty or special formulation. H. R. Noble Ltd., 236 North Circular Road, Palmers Green, London N.13.

**EMD 5757** for further information



# HETRON* RESINS

Hetron Resins, polyesters based on Het* Acid, are rapidly being acclaimed as new and versatile fabricating materials. As well as offering all the advantages of normal low-temperature-setting polyesters, Hetron Resins do not support combustion. When the source of heat is removed, flames die immediately. *Fire cannot spread.*

*In addition, Hetron Resins offer fabricators:*

- High strength with light weight
- Non-deterioration of fire-retarding properties in all climates
- Resistance to corrosion and chemical attack
- Resistance to temperatures up to 150°C.

*Please write to us for full details of the many applications of Hetron Resins*

**ALBRIGHT & WILSON (Mfg) LTD.**

Section HR6, Organic Chemical Dept.,
1 Knightsbridge Green, London, S.W.1. Tel: KENsington 3422

## IN ENGINEERING

Glass fibre reinforced polyesters have long been used for many types of plant construction. Polyesters based on Het Acid are chemically resistant and provide the great additional advantage of being self-extinguishing. One such resin allows laminates with glass mat to retain 70% of its original room temperature strength when measured at 150°C. after ageing for 192 hours at 150°C. Such laminates are also resistant even to glacial acetic acid which attacks most other polyester resins.

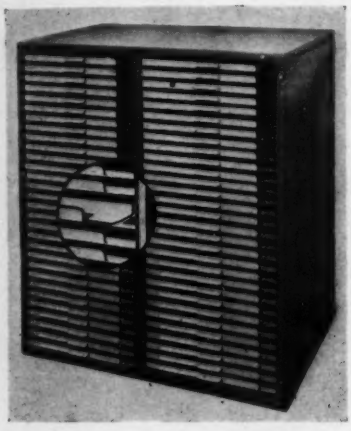
* *Registered Trade Mark*

# WHAT'S NEW IN THE OFFICE

## Storage of Drawings

Ranplan is a steel cabinet for the storage of drawings in the flat, with trays of 1 in. depth. This allows for batches of drawings to be kept in suitable groupings for speedy reference. The cut-away section of the right-hand corner of each tray enables easy location without undue handling of the drawings.

The trays are of an envelope design to prevent drawings from being damaged or lost down the back of the cabinet, and all are fitted with press-formed radiused handles and ticket strip holders for identification purposes.



The cabinet is designed in three sizes to give thirty, sixty and ninety trays covering the popular sizes of drawings in use. Ranplan is particularly useful for all types of paper, board and plastic sheeting, where storage in the flat is essential. Locking doors can be fitted to all sizes of cabinets where required. J. H. Randall & Son Ltd., Paddington Green Works, London, W.2.

**EMD 5758** for further information

## Calculating Machine

A new Facit calculating machine which incorporates a unique transfer feature has been introduced. It is in the 'ten-key' range, is silent in operation and incorporates complete tens-transmission. The new transfer feature allows the operator to transfer the result of any multiplication back on the setting register at the speed of clearance. At the same time the product and multiplier registers are automatically cleared. The necessity for resetting partial results has also been eliminated, as the operator can now transfer the figures in the multiplier register to become the next multiplicand or dividend.

This new machine (the CM 2.16) is portable, and, in addition, is fitted with rollers so that it can be moved out of the way when not in use. Its working capacity is 11 × 9 × 16. Block & Anderson Ltd., Pemberton House, East Harding Street, London, E.C.4.

**EMD 5759** for further information

## Drawing Table

The Admel Hemsley drawing table is said to combine all the advantages of both floor and bench-mounted-type drawing stands. The main features of the table are that the drawing stand and counterbalancing mechanism are built in to the reference unit, giving the following benefits: it is fully counter-balanced, has front controls giving finger-light height and angle adjustment; takes all types of drafting machines; has ample drawer space; provides easy side and rear reference; and is extremely economical in regard to floor space. In appearance the table is both modern and functional. Lawes Rabjohns Ltd., Abbey House, Victoria Street, Westminster, London, S.W.1.

**EMD 5760** for further information

## New Publications and Technical Literature

**Sandvik Steel Works Co. Ltd.:** Book of 175 pages containing information on virtually every aspect of stainless-steel tubes, including detailed information on stainless-steel grades, manufacturing methods, tempers and finishes, fabrication and welding. Sandvik Swedish Steels Ltd., Manor Lane, Halesowen, Birmingham.

**EMD 5761**

**Engelhard Industries Ltd.:** Leaflet describing improvements in the Atomex electroless gold deposition process. Baker Platinum Division, 52 High Holborn, London, W.C.1.

**EMD 5762**

**Plasinter Co. Ltd.:** 15-page illustrated catalogue of the company's range of plastics finishes for all surfaces. Progress Works, Holyhead Road, Wednesbury, Staffs.

**EMD 5763**

**Porous Plastics Ltd.:** Brochure giving details of the main applications of Vyon, which is a new porous high-density polyethylene of the Ziegler type. Dagenham Dock, Essex.

**EMD 5764**

**Imperial Aluminium Co. Ltd.:** 28-page booklet of data on the Impalco aluminium alloy lorry body sections (Mark 3 series). P.O. Box 216, Birmingham, 6.

**EMD 5765**

**English Electric Valve Co. Ltd.:** 28-page booklet on the E702, which is a storage tube of the direct view type designed to provide brilliant displays of information ranging from single transients and recurrent waveforms to composite pictures containing half-tones. Chelmsford, England.

**EMD 5766**

**Imperial Chemical Industries Ltd.:** Brochure of data on silicones, their properties and products. Millbank, London, S.W.1.

**EMD 5767**

**Gordon & Gotch (Sellotape) Ltd.:** "Electrical Taping", a 13-page pocket information booklet giving details of a number of pressure-sensitive adhesive tapes for electrical use. Industrial Division, 8-10 Paul Street, London, E.C.2.

**EMD 5768**

**John Gosheron & Co. Ltd.:** "Tape Digest", a 14-page booklet of data on all kinds of tape. The Packaging & Industrial Tape Centre, Albert Embankment, Vauxhall, London, S.E.11.

**EMD 5769**

**Elcontrol Ltd.:** A duplicated data sheet (FSP3) describing a photo-electric flame-failure unit for oil burners. Wilbury Way, Hitchin, Herts.

**EMD 5770**

**W. C. Holmes & Co. Ltd.:** "Publication No. 85", a brochure of data on Holmes-Connersville positive air blowers (type RBS), which have recently been modified to give improved performance. P.O. Box B.7, Turnbridge, Huddersfield.

**EMD 5771**

**Plywood Manufacturers Association of British Columbia:** 23-page booklet describing the manufacture of Canadian Douglas fir plywood, the phenolic resin glue used in its production, and some of the many end uses to which fir plywood can be adapted. 4 Carmelite Street, London, E.C.4.

**EMD 5772**

**The Incandescent Heat Co. Ltd.:** 7-page reprint of an article by W. S. Sinclair, entitled "Refractory Suspended Construction". Cornwall Road, Smethwick, Birmingham.

**EMD 5773**

**The Trent Valve Co. Ltd.:** 130-page catalogue of the firm's valves, beautifully bound and illustrated. 47 Great Eastern Street, London, E.C.2.

**EMD 5774**

**Barflo Ltd.:** Leaflet giving details of the Barflo high-density polythene ball valve with an all-direction adjustable arm. 56 Cavendish Place, Eastbourne.

**EMD 5775**

**EMD 5644** for further information

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# News of Industry

**Yorkshire Imperial Metals Ltd.** and **Imperial Chemical Industries Ltd.** have combined their activities in marketing polythene tube. In consequence, the combined product of the two companies will be known as Polyorc-Alkathene. These tubes are made to BS 1972 and 1973, and for plumbing installations they can be jointed by conventional fittings designed for copper tubing, as well as by a number of fittings specifically designed for polythene tubing.

Step, the new name in the Univac computer range, is a new "expandable" electronic data processing system developed by **Remington Rand**. Step has been designed to allow managements of the smaller organisations to benefit from the efficiency inherent in electronic data processing. The same machine can also be expanded to serve larger organisations.

Joseph Lucas (Hydraulic and Combustion Equipment) Ltd. will in future be known as **Lucas Industrial Equipment Ltd.** The main policy of the new company is the exploitation of the industrial market for hydraulic equipment, including hydrostatic drives for a large variety of transporting equipment and machinery. In conjunction with government and university institutions, additional applications are being constantly explored.

In addition, the official title of Joseph Lucas (Gas Turbine Equipment) Ltd. has been changed to **Lucas Gas Turbine Equipment Ltd.** This firm is prominent in the field of research, design, development and manufacture of gas turbine fuel systems, and is also well known and established in the research, design, development and manufacture of combustion equipment for aircraft gas-turbine engines, and equipment for aircraft hydraulic systems. It has factories in Birmingham, Liverpool, Burnley, Canada and Australia, and its products are manufactured under licence throughout the Western hemisphere.

The latest U.S. 1,250-h.p. Solar gas turbine, Saturn, is now being marketed by **Perkins Gas Turbines Ltd.**, a subsidiary of F. Perkins Ltd. Available in both constant and variable-speed versions, the Saturn gas turbine is claimed to be one of the most efficient engines of its type. It is particularly suitable for hydrofoil designs, where high power and light installation weight are essential to overcome "hump" resistance. A direct drive of 20,000 r.p.m. is available for use with the latest designs of high-speed air and gas compressors, thus reducing first cost and maintenance of reduction gearing. The basic Saturn engine (*right*) weighs 950 lb. and can be operated efficiently on most types of fuel, including petrol, paraffin, diesel, jet fuels and natural or manufactured gas.

Closed-circuit television enables one attendant in a central control room at the Sunderland gasworks to take all the necessary operational readings from meters, gauges and other instruments situated in different parts of the building. This system, installed by **Pye Ltd.**, works on 625 lines and has five T.V. cameras strategically positioned to send pictures to an 8½-in screen in the control room. Using a five-way camera switching unit, the attendant can bring to the screen pictures from any one of the cameras. The camera is then directed by remote control units on to any instrument which the attendant wishes to read.

A new method of heating glass feeders by electricity has been developed by the **Morgan Crucible Co. Ltd.**, using Crusilite heating elements. An extremely high quality output is said to be obtained, the possibility of contamination by flame impingement and products of combustion being eliminated. Proportional band controllers and radiation pyrometers ensure accurate temperature control of feeder and spout, and achieve a fast response with minimum attention. Gob temperature can be maintained within narrow limits, thus obviating the risk of distortion. Experience suggests that the cost of running an electric feeder will compare very favourably with existing methods, the initial cost of installation or conversion being about the same.

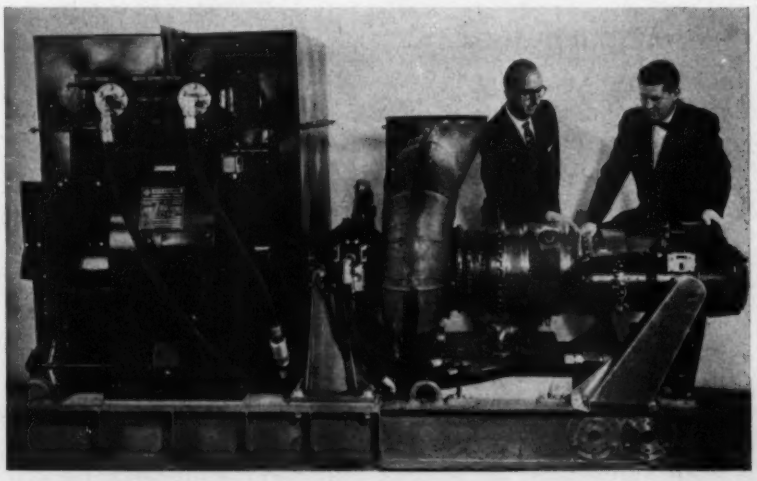
A complex system of unplasticised p.v.c. fume extraction pipework, fabricated and installed by **Extrudex Ltd.** at the new Royston platinum refinery of Johnson, Matthey & Co. Ltd., has now been working satisfactorily for three years. The ductwork extracts from a succession of refining pans highly corrosive fumes, which are carried away through p.v.c. eliminator boxes and scrubbing towers before release to the atmosphere. Previously, the only possible material for such an installation would have been stoneware or glass. The availability of p.v.c. pipework enabled this precious-metal refining plant to solve the problems of handling these materials.

Substantial reductions in the price of Ambersil and Amber Electrospray have been made by **Amber Oils Ltd.** Ambersil Formula One is an aerosol-packed pure methyl silicone fluid of high lubricity, high heat resistance and low surface tension. It is widely used as a mould release agent and lubricant in industries manufacturing, processing or using plastics, wax-coated papers, synthetic fibres and natural and synthetic resins, and in aluminium die casting and the shell-moulding and $CO_2$ processes. Formula Two consists of the same pure methyl silicone, but with the addition of an appropriate solvent which makes for a finer spray and thinner film. It is used in specialised applications where lower flash and ignition points are acceptable. The Amber Electrospray is an anti-tracking and anti-corrosive formulation for the protection of electrical equipment against condensation, corrosion and verdigris.

In the design of much engineering equipment it is becoming increasingly important to know the capabilities of the human operator. A most useful bibliography of some of the more generally useful and significant information appeared in the September 12, 1960, issue of the American journal *Product Engineering*. All the literature and the list of organisations and research centres given are American.

## MEETINGS AND EXHIBITIONS

A joint committee, of which Professor G. A. Whitfield, of the College of Aeronautics, Cranfield, is the chairman, was recently formed by the councils of the **Institution of Electrical Engineers** and of the **Royal Aeronautical Society** to consider ways and means of stimulating discussion on the applications of electricity in aircraft. It is intended that meetings of the joint groups should be informal, and in the nature of colloquia designed to interest technicians as well as aeronautical and electrical engineers.



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